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TECHNICAL REPORT

of

OPERATION CROSSROADS [U]. 8

Prepared for Commander Joint Task Force One
for Transmittal to the Joint Chiefs of
Staff and their Evaluation Board

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PREFACE

This History, the Technical Report on Operation Crossroads, was begun on 29 Jan 46 at the request of Vice Admiral W. H. P. Blandy, Commander JTF-1. Preparation was guided principally by Rear Admiral W. S. Parsons, Deputy Commander for Technical Direction.

The History is based largely on Commander JTF-1 Operation Plan, No. 1-46, on the various administrative and technical histories, reports by the many groups within Joint Task Force One, and on material gathered from correspondence, interviews, and inspections. Care has been taken to locate authoritative sources for the facts presented. A file has been kept showing the sources of all significant facts. Since many of the data included are still in a non-final state, it is likely that a number of minor changes will be in order in the following months.

The History does not, of course, take the place of the detailed reports prepared by the various JTF-1 groups and identified in the Bibliography; it attempts mainly to combine in one unified work the salient parts of the many basic reports.

The History discusses failures as well as successes. A prominent research director has said "Every honest researcher I know admits he's just a professional amateur. He's doing whatever he's doing for the first time. That makes him an amateur. He has enough sense to know that he's going to have a lot of trouble, so that makes him a professional."

A "finder tab" system is included whereby the reader may turn instantly to any desired chapter on results.

To the many persons who helped in the preparation of this History I extend my thanks.

William A. Shurcliff

W. A. Shurcliff
Historian, JTF-1
18 Nov 46

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Chapter 10

Execution of Test A

10.001 Introduction.

This Chapter describes the execution of Test A. It makes no attempt to cover the objects of the Test (see Chap. 2), organization, administration, nontechnical preparations, or rehearsal (see Chap. 3), or the technical results, which are covered in Chaps. 11 through 19.

10.002 Delivery of Bomb.

Bomb A, dubbed "Gilda," was put aboard the specially-prepared B-29 bombing plane "Dave's Dream," Aircraft No. 44-27354, at Kwajalein at approximately 1230, 30 June 46, Bikini local time (i.e., time in minus eleven time zone). Loading was facilitated by use of the specially-constructed loading ramp on the south side of the western end of the runway.

The men who boarded Dave's Dream were:

Maj. W. P. Swancutt	Airplane Commander
Brig. Gen. R. M. Ramey	Task Group 1.5 Commander
Col. W. J. Blanchard	Air Attack Commander
Capt. W. C. Harrison, Jr. (Army)	Co-Pilot
Maj. H. H. Wood	Bombardier
Col. J. R. Sutherland	Bomb Commander
Ens. D. L. Anderson	Weaponeer
Mr. L. D. Smith	Weaponeer
Capt. Paul Chenchar, Jr. (Army)	Radar Observer
Maj. W. B. Adams	Navigator
Lt. R. M. Glenn (Army)	Flight Engineer
Corp. R. M. Modlin	Scanner
Corp. H. B. Lyons	Scanner
Tech. Sgt. J. W. Cothran	Radio Operator

At the originally scheduled hour of takeoff, 0534, Dave's Dream was standing on the loading ramp, loaded and ready. The go-ahead signal from Commander JTF-1 was relayed at 0542 from MT. MCKINLEY to ALBEMARLE moored at Kwajalein and was immediately transferred to the Commander Task Group 1.5. Three minutes later, at 0545, Dave's Dream taxied down the ramp towards the takeoff position at the

west end of the runway. Takeoff occurred at 0555.

At 0547 How Hour had been postponed by Commander JTF-1 because of cloud conditions at Bikini and because clear weather was expected at a later time. X-Ray hour, the scheduled time of arrival at stations, was changed from 0649 to 0719. The postponement, besides allowing time for the cloud coverage to lessen, made it possible for the command aircraft of Task Group 1.5 (which had arrived on station at 0527 at an altitude of 23,000 ft) to make a last minute reconnaissance upwind to increase the reliability of predictions as to the cloud cover which would exist at Bikini at How Hour.

Plans had previously been made to shorten the route of Dave's Dream to the target area to compensate for any delay in takeoff. However, 3 min after takeoff, notice of the 30-min postponement of How Hour was received. Therefore Dave's Dream proceeded as originally briefed. It reached bombing altitude over Wotho Atoll, and arrived over the target area at 0803. It made the prescribed wind run to Orbit Point Baker. The Bomb Commander and weaponeers completed their final tests and adjustments.

The one dry run began at 0820. During this run, the Edgerton flasher on NEVADA was seen clearly. Also the radar beacon at Bikini was picked up 50 mi away and was used to time the approach and maintain the desired course, which was 045° (True). The bombardier's recognition of the target center was further aided by the white turrets of NEVADA. Visibility was excellent. Simulated release was at 0831. The dry run was considered successful. Ballistic wind data (13[illegible] mi/hr from 128° True) were obtained by radio from MT. MCKINLEY.

At 0849, CUMBERLAND SOUND reported ready for the live bombing run; whereupon Commander JTF-1 gave the command to start.

Meanwhile Dave's Dream had started back to Orbit Point Baker. It began the live run at 0850, bearing 225° (True), distance 50 nautical miles from target. It passed the Initial Point bearing 225° (True), at a distance 35 nautical miles from target, and continued on to target.

At 0900, the cloud coverage, which had been 0.2 to 0.3 at 0830, had decreased to 0.1 to 0.2. The wind encountered was 11½ mi/hr from 1[illegible]° (True).

Bombing altitude of (nominally) 29,000 ft was maintained; calibrated indicated air speed was 190 statute mi/hr; true air speed was 299 mi/hr. The following is a quotation from Part III, Sec. E, of Air Operations Report of Operations Crossroads by Commander Task Group 1.5: "The bombardier corrected for wind and bomb weight, and added a small compensation for the inherent tendency to hit short with KN bombs. (KN bombing tables were used in all computations.)"

The report referred to above continues (p. 79): "Timing was very nearly perfect. Accepting actual release as the basis for measuring errors, the 10-min signal was 14 sec late, the 5-min signal was 12 sec late, the 2-min signal was 8 sec late, and the 1-min signal was only 3 sec late. Release occurred at 0859:46, exactly 14 sec early."

At the instant the bomb was released, the bombardier broadcast "Bomb Away, Bomb Away."

A report by the Air Attack Commander stated: "The Bomb Commander watched the bomb clear the airplane and stated it did not hit any part of the Bomb Carrier."

A few seconds after release of the bomb (bomb-bay doors closed within 3 to 8 sec) the pilot executed a 150° level turn to the left and then executed a shallow dive, losing 1000 ft while increasing calibrated indicated air speed to 240 mi/hr. The shock wave was felt in the plane 84 sec after release and the secondary wave was felt immediately thereafter. Neither affected control of the plane.

"Dave's Dream" returned to Orbit Point Baker and from there went directly to base at Kwajalein, landing without incident.

Eggleston Eight, the F-13 photographic plane, rendezvoused with "Dave's Dream" at 0803. It accompanied Dave's Dream on all runs, maintaining position 1000 ft to the right. It took motion pictures of Dave's Dream and of the bomb falling (35-mm black and white film, Serial No. Cr. 18248). It then broke away, turning 150° to the right, photographing the bomb throughout its fall and photographing the explosion.

Pictures taken from Dave's Dream gave a pictorial record of the line of flight prior to the drop and of the drop of the bomb throughout the first few seconds.

10.003 Detonation.

The bomb detonated at 34 sec ± 5 sec after 0900 (1 July 46) Bikini local time, which is 34 sec ± 5 sec after 1700 (30 June 46) EST and 34 sec ± 5 sec after 2200 (30 June 46) GCT.

The bomb fell for 48.1 sec ± 0.3 sec before detonating.

Altitude of the bomb at Mike Hour was 518 ft with a probable error of plus or minus 10 ft. (Source: Ref. 300-11)

Final data as to the latitude and longitude of the actual Zero-

point were not available in the office of the Technical Director by 1 Nov 46.

Surface atmospheric conditions in the Lagoon at Mike Hour were as follows:

Dry bulb temperature	30° C	(86° F)
Wet bulb temperature	25.3°C	(77.5°F)
Pressure	1012.2 millibars	(29.888 in. of mercury)
Relative humidity	68 percent	
Dew Point	23.3° C	(74° F)
Wind	East Northeasterly 8 knots	
Visibility	15 mi	
Velocity of Sound	350 m/sec	

Wind direction and velocity at 0905 were as follows:

Altitude (ft)	Direction (° True)	Velocity (knots)
0	80	8
1000	130	15
2000	130	13
3000	130	13
4000	130	14
5000	140	14
6000	140	15
7000	120	15
8000	120	11
9000	130	11
10,000	-	-
12,000	120	7
14,000	100	9
15,000	100	7
16,000	070	8
18,000	320	2
20,000	330	4
22,000	210	5
24,000	150	16
25,000	180	8
28,000	120	4
30,000	340	6
35,000	340	2
40,000	070	8
45,000	030	26

At 1020 temperature and humidity values at various altitudes were as indicated below:

Altitude (ft)	Temperature (°C)	Relative Humidity (percent)
Surface	28	80
10,000	28	80
15,000	21	80
20,000	12	60
30,000	-5	90
35,000	-12	90

10.004 Status of Target Vessels.

Table 10.1 shows the A-Day, Mike Hour positions and aspects of the target vessels.

Fig. 10.1 is a chart of the Test-A target array showing positions of target vessels relative to projected Zeropoint on A-Day at Mike Hour.

Table 10.2 shows the conditions of target vessels within 1000 yd of the Zeropoint as regards fuel and ammunition loads:

10.005 Status of Other Targets.

(A) Airborne Targets. Four Army and three Navy drones were airborne on A-Day at Mike Hour. They were located as follows at Mike Hour:

Drone	Altitude (ft)	Approx. Slant Distance from Zeropoint (Nautical Miles)	Bearing from Zeropoint (° True)
B-17 Fox	24,000	20	270
B-17 George	30,000	30	045
B-17 How	18,000	30	045
B-17 Love	13,000	30	045
F6F Yellow Dog	10,000	20	312
F6F Blue Dog	15,000	20	312
F6F White Dog	20,000	20	312

(B) Shore Targets. Eighteen landing craft were exposed on the beach at Bikini between 5500 and 6000 yd from Zeropoint. These included:

Type	Quantity	Identifying No.
LST	1	133
LCI	2	615,620
LCT	4	414,812,1175,1237
LCM	5	2,3,4,5,6
LCVP	6	7,8,9,10,11,12

(C) Other Targets. Two PB2Y-5E Coronado seaplanes were on the surface between 2600 and 3350 yd from the Zeropoint, bearing approximately 270° True.

One pontoon bridge was moored to the stem of the ARDC-13.

10.006 Status of Personnel.

Practically the entire complement of personnel in the Bikini area observed the explosion. Many persons wore special protective goggles; others took the prescribed precautionary measures of facing away from the Zeropoint and covering their eyes with their forearms.

Nearly all of the personnel were aboard the non-target surface vessels; some, including special observers, were aboard aircraft. No persons were aboard the target vessels.

Nearest non-target vessels, between 11.7 and 15 nautical mi from Zeropoint, were:

Appling	Haven
Artemis	Henrico
Avery Island	Laffey
Barton	Mt. McKinley
Begor	O'Brien
Burleson	Walke
Cumberland Sound	Wharton
	Whiting

The nearest manned planes at Mike Hour were B-29 Dave's Dream and F-13 (photographic plane) Eggleston Eight, both at an altitude of approximately 28,000 ft. The shock wave produced no more noticeable effect than the planes' encountering normal propeller wash.

TABLE 10.1. RELATIVE POSITIONS OF TARGET VESSELS ON A-DAY AT MIKE HOUR.

Vessel	Range fm Burst to Bow (Yd)	True Bearing of Bow from Burst		Relative Bearing of Burst from Bow		Coordinates of Vessel from Burst (Yd)				Distance from Burst to Nearest Part of Vessel (Yd)	Direction of Burst from Vessel
						Bow		Stern			
		deg	min	deg	min	X	Y	X	Y		
Battleships & Cruisers											
Arkansas, BB 33, 562*	779	54	40	150	15	632 E	443 N	457 E	427 N	621	Stbd. Qtr.
New York, BB 34, 573	1729	107	46	59	04	1643 E	539 S	1499 E	419 S	1547	Stbd. Qtr.
Nevada, BB 36, 583	792	99	24	192	09	777 E	134 S	595 E	139 S	615	Stern
Pennsylvania, BB 38, 608	1743	150	03	208	22	841 E	1505 S	664 E	1397 S	1541	Port Qtr.
Pensacola, CA 24, 586	898	82	33	172	45	883 E	111 N	704 E	109 N	710	Stern
Salt Lake City, CA 25, 586	1018	136	23	228	00	698 E	743 S	501 E	745 S	895	Port Qtr.
Nagato, JAP BB,	1015	112	22	198	44	935 E	393 S	692 E	371 S	782	Port Qtr.
Sakawa, JAP CL,	607	81	58	177	40	595 E	91 N	411 E	61 N	420	Stern
Prinz Eugen, IX 300,	1194	298	04	343	40	1041 W	588 N	1218 W	737 N	1194	Bow
Aircraft Carriers											
Saratoga, CV 3, 910	2563	129	52	183	10	1951 E	1661 S	1713 E	1480 S	2263	Stern
Independence, CVL 22, 619	699	125	27	223	34	563 E	410 S	365 E	436 S	560	Port Qtr.
Destroyers											
Lamson, DD 367, 344	768	36	38	92	43	455 E	619 N	369 E	671 N	762	Stbd. Beam
Conyngham, DD 371, 344	3247	113	58	154	26	2955 E	1345 S	2883 E	1259 S	3145	Stbd. Qtr.
Mugford, DD 389, 341	2802	114	03	173	43	2549 E	1164 S	2455 E	1106 S	2690	Stern
Talbot, DD 390, 341	1245	90	12	139	20	1239 E	13 S	1159 E	62 S	1163	Stbd. Qtr.
Mayrant, DD 402, 341	3614	220	00	280	18	2358 W	2740 S	2448 W	2686 S	3614	Port Beam
Rhind, DD 404, 341	1012	07	27	61	14	135 E	1004 N	49 E	1067 N	1012	Stbd. Bow
Stack, DD 406, 341	1332	340	56	31	39	427 W	1264 N	511 W	1333 N	1332	Stbd. Bow
Wilson, DD 408, 341	1480	324	29	24	06	851 W	1209 N	941 W	1265 N	1480	Stbd. Bow
Hughes, DD 410, 348	1028	96	32	192	10	1019 E	123 S	907 E	105 S	922	Stern
Anderson, DD 411, 348	636	180	57	247	43	13 W	638 S	117 W	589 S	598	Port Beam
Mustin, DD 413, 348	2262	112	46	169	05	2079 E	893 S	1979 E	824 S	2147	Stern
Wainwright, DD 419, 348	2159	307	05	342	55	1713 W	1314 N	1778 W	1404 N	2159	Port Bow
Submarines											
Skipjack, SS 184, 299	1204	149	36	211	55	599 E	1043 S	512 E	996 S	1122	Port Qtr.
Searaven, SS 196, 310	1856	47	37	126	30	1381 E	1239 N	1279 E	1259 N	1798	Stbd. Qtr.
Tuna, SS 203, 299	2194	31	10	75	53	1159 E	1863 N	1103 E	1935 N	2194	Stbd. Bow
Skate, SS 305, 311'6"	483	111	27	211	29	447 E	179 S	344 E	196 S	400	Port Qtr.
Apogon, SS 308, 311'6"	1031	165	38	201	04	252 E	1006 S	189 E	916 S	940	Stern
Dentuda, SS 335, 311'6"	1948	72	15	101	23	1856 E	581 N	1814 E	664 N	1930	Stbd. Beam
Parche, SS 384, 311'6"	1366	199	55	270	55						
Pilotfish, SS 386, 311'6"	2506	49	27	68	19	1889 E	1647 N	1779 E	1690 N	2506	Stbd. Beam
Landing Craft											
LST 52, 328	1539	30	42	82	02	793 E	1319 N	713 E	1381 N	1532	Stbd. Beam
LST 220, 328	3272	09	33	34	06	578 E	3221 N	533 E	3322 N	3272	Stbd. Bow
LST 545, 328	4067	10	53	130	07						
LST 661, 328	2320	21	11	60	11	838 E	2162 N				

* Length of Ship in Feet

TABLE 10.1. RELATIVE POSITIONS OF TARGET VESSELS ON A-DAY AT MIKE HOUR. (con't)

Vessel	Range fm Burst to Bow (Yd)	True Bearing of Bow from Burst		Relative Bearing of Burst from Bow		Coordinates of Vessel from Burst (YD)				Distance from Burst to Nearest Part of Vessel (Yd)	Direction of Burst from Vessel
						Bow		Stern			
						X	Y	X	Y		
Landing Craft (con't)		deg	min	deg	min						
LCI 327, 159*	2481	92	48	134	45	2477 E	141 S	2445 E	104 S	2441	Stbd. Qtr.
LCI 329, 159	2892	94	56	59	35	2879 E	273 S	2909 E	233 S	2892	Stbd. Bow
LCI 332, 159	2265	95	44	193	56	2252 E	246 S	2189 E	253 S	2217	Stern
LCI 549, 159	4553	92	19	135	19	4549 E	185 S				
LCT 745, 120	3807	273	07	323	07						
LCT 816, 120	1361	79	48	152	54	1331 E	235 N	1298 E	245 N	1318	Stbd. Qtr.
LCT 818, 120	1498	71	59	89	30	1429 E	451 N	1413 E	501 N	1495	Stbd. Beam
LCT 874, 120	2544	62	00	113	45	2256 E	1174 N	2222 E	1201 N	2519	Stbd. Qtr.
LCT 1013, 120	4067	285	48	351	48						
LCT 1078, 120	3279	57	52	116	47	2792 E	1719 N	2755 E	1740 N	3254	Stbd. Qtr.
LCT 1112, 120	3904	56	19	105	12	3266 E	2138 N	3232 E	2167 N	3886	Stbd. Beam
LCT 1113, 120	4217	55	39	109	27	3582 E	2409 N	3564 E	2431 N	4195	Stbd. Beam
LCM 1,						863 E	31 S	839 E	23 S		
Merchant Craft											
Gilliam, APA 57, 426	47	329	53	22	33	28 W	44 N	139 W	127 N	47	Bow
Banner, APA 60, 426	1312	112	39	164	15	1209 E	513 S	1094 E	427 S	1180	Stern
Barrow, APA 61, 426	1334	255	56	310	46	1298 W	311 S	1416 W	233 S	1334	Port Bow
Bladen, APA 63, 426	2910	156	17	216	02	1145 E	2673 S	1025 E	2606 S	2810	Port Qtr.
Bracken, APA 64, 426	2160	143	36	190	56	1272 E	1749 S	1155 E	1677 S	1842	Port Qtr.
Briscoe, APA 65, 426	1712	120	25	181	11	1469 E	876 S	1345 E	806 S	1575	Stern
Brule, APA 66, 426	1094	67	37	129	58	1011 E	407 N	889 E	471 N	1005	Stbd. Qtr.
Butte, APA 68, 426	1973	250	38	307	38						
Carlisle, APA 69, 426	429	228	38	281	44	328 W	279 S	443 W	193 S	429	Port Bow
Carteret, APA 70, 426	1757	79	52	125	11	1732 E	294 N	1636 E	394 N	1677	Stbd. Qtr.
Catron, APA 71, 426	1895	132	52	185	38	1382 E	1296 S	1269 E	1213 S	1764	Stern
Cortland, APA 75, 426	3140	242	52	299	52						
Crittenden, APA 77, 426	594	282	00	344	57	581 W	127 N	708 W	191 N	594	Bow
Dawson, APA 79, 426	853	257	02	311	30	835 W	183 S	946 W	103 S	853	Port Bow
Fallon, APA 81, 426	1414	140	06	203	05	899 E	1093 S	775 E	1026 S	1290	Stern
Fillmore, AFA 83, 426	2568	151	02	206	00	1229 E	2256 S	1115 E	2173 S	2453	Port Qtr.
Gasconade, APA 85, 426	2687	245	41	302	41						
Geneva, APA 86, 426	3162	160	00	217	30	1059 E	2979 S	939 E	1905 S	3062	Port Qtr.
Niagara, APA 87, 426	3407	162	45	222	20	983 E	3261 S	865 E	3189 S	3318	Port Qtr.
Concrete Drydocks & Barges											
YO 160	638	90	48	198	22	637 E	11 S	520 E	51 S	520	Port Qtr.
YOG 83	1134	56	09	137	20	949 E	621 N	825 E	639 N	1041	Stbd. Qtr.
ARDC 13	835	180	55	272	06	28 W	834 S	160 W	944 S	827	Port Beam

* Length of Ship in Feet.

TOP SECRET

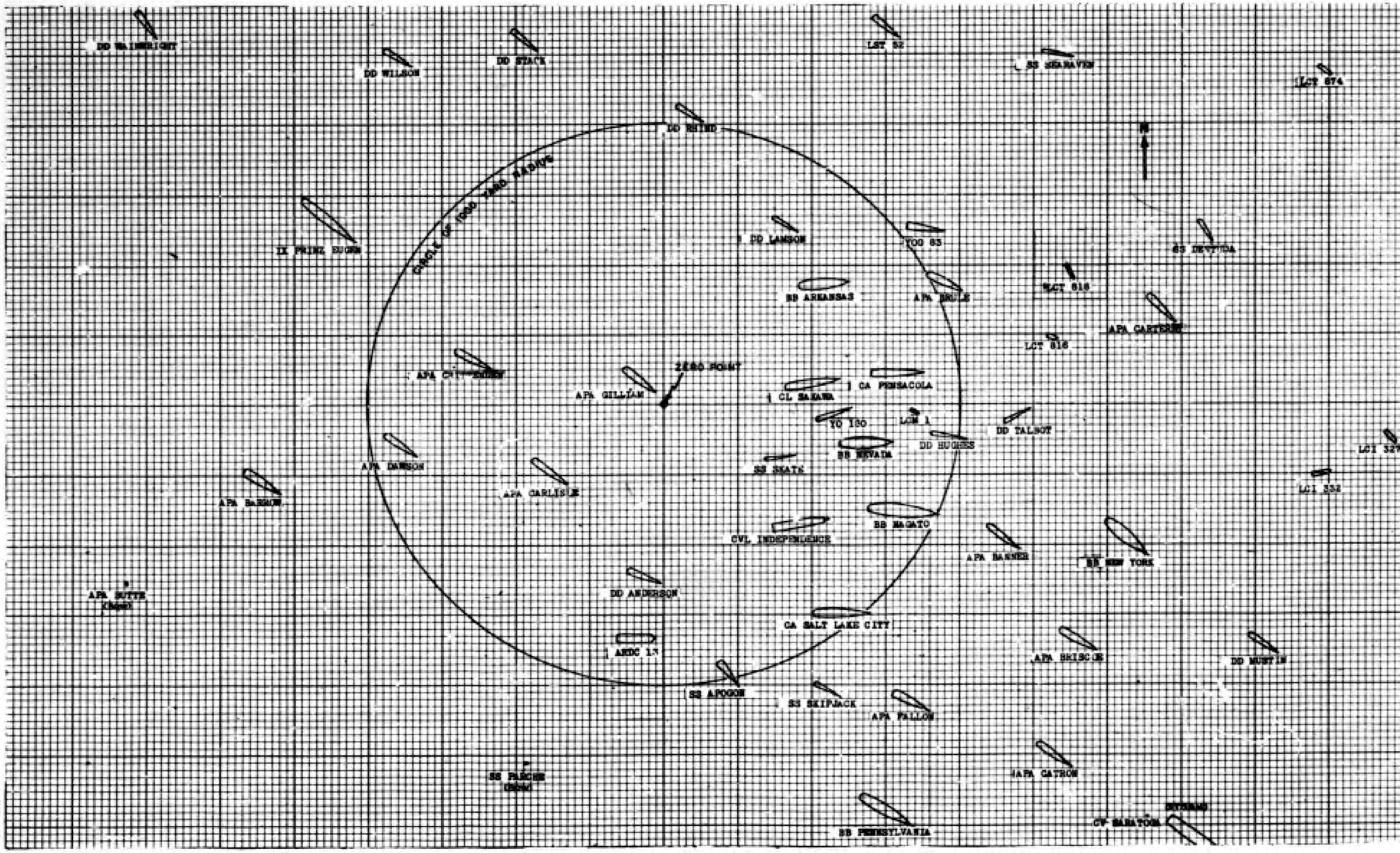

FIGURE 10.1. TEST-A TARGET ARRAY [INNER PORTION] SHOWING POSITIONS OF TARGET VESSELS RELATIVE TO PROJECTED ZEROPOINT ON A-DAY AT MIKE HOUR.

Table 10.2

Test-A Fuel and Ammunition Loads on Target Vessels Within 1000 Yd.

Note: Percentages refer to percentages of normal load (abbreviated N). Normal load ordinarily means approximately 95 percent of capacity. M indicates minimum load, ordinarily approximately 10 percent of capacity.

Target Vessel	Fuel Load (percent)	Ammunition Load (percent)
Battleships & Cruisers		
Arkansas	50	50
Nagato	15	M
Nevada	33	67
Pensacola	15	67
Sakawa	33	0
Salt Lake City	M	M
Aircraft Carriers		
Independence	33	67
Destroyers		
Anderson	N	N
Hughès	15	67
Lamson	50	50
Rhind	50	50
Submarines		
Apogon	50	50
Skate	33	67
Attack Transport Merchant Type		
Brule	M	M
Carlisle	N	N
Crittenden	N	N
Dawson	50	50
Gilliam	50	50
Other Craft		
ARDC - 13	0	0
YOG - 83	0	0
YO - 160	0	0

Other major equipment aboard vessels included:
- Special Test Ammunition
- Tanks, guns, trucks
- 73 Navy aircraft

10.007 Re-entry.

Re-entry in Bikini Lagoon proceeded according to schedule.

A. Re-entry by Drone Planes. Drone planes played an important part in the "re-entry." Shortly after Mike Hour, at 0908, an Army B-17 drone plane entered the cloud at 24,000 ft followed in a few minutes by three other B-17 drones, at altitudes of 30,000, 18,000, and 13,000 ft. Navy F6F drones flew thru the cloud at 20,000, 15,000, and 10,000 ft. After having successfully collected air samples, the drones returned to base. The samples were then transferred to Kwajalein for analysis.

B. Re-entry by Drone Boats. To help control the LCVP drone boats, four TBM planes with drone boat conning officers and radiological safety monitors aboard, were launched from SAIDOR a few minutes after Mike Hour. Shortly afterwards, BEGOR (drone boat control vessel) approached the Lagoon (outside Bikini-Enyu reef) for visual control of the drone boats.

At 0944 the first LCVP drone started towards the target array; the other started soon afterwards. The first LCVP reached the target center at 1045 and began picking up water samples at 1101; it evacuated the area at 1136. By 1300 a number of water samples had been transferred to MOALE, which was soon speeding to Kwajalein where the samples were analyzed.

C. Re-entry by Manned Planes. Two radiological reconnaissance PBM's, "Charlie" and "Dog," were the first manned planes to fly into the immediate vicinity of the target array. Leaving their stations shortly after Mike Hour, they moved to positions 5 nautical miles upwind from the Zeropoint; at 0952 "Charlie" began traversing the target area in parallel sweeps, "Dog" following at 1055. At 1310 "Dog" flew directly over the Zeropoint at 3000 ft.

D. Re-entry by Manned Vessels. At 0947 radiological clearance was given to BARTON to go to the Lagoon entrance and for the (Wave 1) 6 PGM's of the radiological safety party to follow her. Shortly afterward, Commander JTF-1 directed Wave 7A (Task Unit 1.2.8; APPLING, ARTEMUS, and HENRICO with the radiological safety party's 20 LCPL's aboard) to enter the Lagoon and lower the LCPL's. By 1050 the PGM's had entered the Lagoon. By 1125 Wave 7A had completed launching the LCPL's, which thereupon entered the Lagoon.

The FALL RIVER anchored on station in Enyu Channel at 1202 and served as harbor entrance control vessel. By 1430 the Lagoon was declared safe for the entrance of all vessels. Vessels of the Technical Group 1.1 entered at 1425; the MT MCKINLEY entered at 1500.

Salvage vessels (Waves 3 and 4) entered at 1300 and by 1402 were engaged in fighting fires aboard some ships.

By sundown on A-Day, 18 vessels had been reboarded by initial boarding teams although no ships' teams had been placed aboard. Some fires persisted.

10.008 Sinkings.

Salient data on sinkings and times of sinking are recorded below: (See Chap. 13 for details).

GILLIAM (APA-57) sank within about one minute after Mike Hour.

ANDERSON (DD-411) by 0908 had rolled over and sunk.

CARLISLE (APA-69) had sunk by 0940. She was burning vigorously amidships shortly after Mike Hour.

LAMSON (DD-367) sank between 1400 and 1700. She capsized to starboard (towards the Zeropoint) and was seen floating bottom up until about 1400.

SAKAWA sank at 1044 one day after A-Day. A fire burned aboard her until the morning after A-Day. Progressive flooding took place. Attempts were made to beach her, but soon after being taken in tow, she keeled over to port and sank by the stern.

Chapter 11

Summary of Results of Test A

Outline

Section

Chapter 11

Summary of Results of Test A

11.001 Introduction.

Bomb A detonated 518 ft above the surface of Bikini Lagoon at 34 sec after 0900, 1 July 46, Bikini Local Time. Seventy target vessels were exposed to the explosion; their positions were as shown in Table 10.1 of Chap. 10.

Some of the most significant results are summarized very briefly in the following sections. More extensive summaries are presented in the following 8 chapters.

11.002 Energy Release.

The amount of energy released was "normal" for an atomic bomb of the Nagasaki type; a total of 8.0 X 10^{20} ergs of energy was released, equivalent to the total amount of energy released in the exploding of 19.1 kilotons of TNT.

11.003 Damage to Vessels.

A total of 5 vessels sank as a result of the explosion; they were situated in the range: 50 to 760-yd horizontal distances from the projected Zeropoint. (Distances are measured to nearest point of vessel.)

Six (non-sunk) vessels were immobilized; they were situated at ranges of 560 to 920 yd.

11.004 Other Damage.

Tanks and guns suffered no appreciable loss of military efficiency at ranges greater than 600 yd. Light vehicles and other light structures were severely damaged out to 1200 yd.

Electronic equipment and instruments were seriously damaged out to 1200 yd.

Packaged ammunition remained undamaged at ranges greater than 1000 yd.

Baled and packaged clothing was damaged, primarily by fires, up to 2000 yd; tires were undamaged (except for superficial scorching) at and beyond 600 yd; plastics were damaged at distances as great as 2000 yd.

Nonperishable packaged food at 500 yd was cleared for consumption by four days after A-Day.

11.005 Injury to Animals and Plants.

More than 50 percent of the test animals situated within 1000 yd of the Zeropoint died; between 15 and 30 percent of the test animals in the annulus from 1000 to 2000 yd died; 5 to 15 percent of the test animals outside 2000 yd died.

Air blast (including primary and secondary effects) was the principal cause of injury leading to immediate "loss of military efficiency" of the test animals; however, many of the animals killed by the air blast received lethal dosages of gamma radiation.

Principal cause of delayed deaths was gamma radiation.

11.006 Pressure Data.

Values of peak pressure in air just above the Lagoon surface were: 2000, 53, 10.5, 4.8, and 3.1 psi gage at horizontal distances of 0, 500, 1000, 1500, 2000 yd from the projected Zeropoint. At 26,800-ft altitude and 11,500 yd slant range the peak pressure was 0.17 psi gage.

The duration of the positive pressure pulse was 0.46 sec and 0.75 sec at horizontal distances of 500 and 1000 yd, respectively.

The shock wave in air had an initial "slant range" velocity of over 14,000 ft/sec; at 1/2 mile slant range the wave had a velocity of approximately 1800 ft/sec.

Peak pressure in closed (surviving) vessels never exceeded 2.5 psi gage.

11.007 Radiation and Radioactivity.

The directly-determined value for total amount of energy emitted by the detonation as optical radiation (including ultraviolet, visible, and infrared light) in the spectral range from 3400 to 24,000 A was 1.7 X 10^{21} ergs, although this figure (corresponding to 40 kilotons of TNT) is obviously far too large. At 12 nautical miles the peak illumination was approximately 10 times greater than is produced by noon summer sun and skylight.

The fireball had a maximum surface temperature of roughly 200,000° K; the radius of the fireball was 110 ft at 1 millisecond after Mike Hour and 800 ft at 1 second after Mike Hour.

The great majority of the gamma radiation reaching target vessels reached them within the first 10 seconds. Cumulative gamma radiation dosages at exposed locations at 600, 1000, 1500, and 2000 yd from the projected Zeropoint were 9000, 1800, 220, and 28 roentgens, respectively. The dosage at 1350 yd was approximately 400 roentgens (lethal).

Neutron dosages were not lethal at horizontal distances greater than 550 yd.

11.008 Other Results.

By 150 sec after Mike Hour the cloud had reached an altitude of nearly 5 mi; its maximum width was 9000 ft, and a thin cap, presumed by some to be an ice cap, had formed. By 400 sec after Mike Hour the cloud had reached 7 mi.

Radioactivity from the explosion was detected at many remote sites, including Continental U. S., several days later.

11.009 Correlations.

The following Table presents estimates by the JTF-1 Technical Historian as to the ranges at which specified loss of military efficiency during the first hour after Mike Hour is probable.

Extent of Immediate Loss of Military Efficiency	Range (yd) Typical Ship	Typical Crew	Ship and Crew in Combination
Very Serious	900	700	900
Serious	1000	800	1020
Moderate	1300	900	1300
Slight	1500	1000	1500

Obviously, the weak link as regards immediate loss of military efficiency is the ship itself. If resistance of stacks and (antenna-supporting) masts could be appreciably increased, a reduction of roughly 100 yd could be effected in the range of immediate loss of combined military efficiency.

Shock wave in air is the cause of greatest immediate (i.e., first hour) loss of military efficiency of ships themselves. Shock wave in air competes with optical radiation as the principal cause of immediate loss of military efficiency of crews per se which are situated outside 900 yd. In the annulus from 600 to 900 yd gamma radiation is the principal cause of loss of military efficiency of crews per se; and within 600 yd neutron and gamma radiations compete as the principal cause. Radiation intensities at ranges less than 550 yd are of reduced interest since ships within 550 yd will ordinarily be sunk.

A typical surface combatant vessel will probably be sunk by a pressure wave in air having a peak pressure greater than 35 psi gage; it will probably suffer very serious immediate loss of military efficiency when subjected to a peak pressure greater than 25 psi gage; peak pressures of 20, 15, and 10 psi gage will probably produce serious, moderate, and slight immediate losses of military efficiency, respectively.

Peak pressures of 25 and 4 psi gage will probably produce (respectively) very serious and slight immediate losses of military efficiency of personnel.

11.010 Discussion.

The Operation had no important shortcomings; but these minor imperfections deserve mention: The bomb detonated 710 yd from the intended Zeropoint, for cause unknown; the timing signal relied on

for starting a number of the instruments was sent out a few seconds late, as a result of two errors by the timing signal operator; a number of instrument-starting black boxes failed to operate satisfactorily, for a combination of reasons.

From the technical point of view as well as from the operational point of view the Test was very successful. Graded damage was produced in ships of many types; graded injury was produced in animals of several types; and the principal physical phenomena (causative factors) were evaluated with reasonably high accuracy. A firm basis was established for determining the vulnerability of ships and crews to air bursts of atomic bombs, and for improving future designs and tactics.

Chapter 12

Detonation and Energy Release, Test A

Outline

Chapter 12

Detonation and Energy Release, Test A

12.001 General Appearance

(Only a brief account of the appearance of the detonation is given here. Later chapters discuss in detail the fireball and condensation cloud.)

Test-A Mike Hour (detonation instant) occurred on 1 July 46 at 34 sec (plus or minus 5 sec) after 0900, Bikini local time.

A very intense flash of light was emitted by the bomb during the first two seconds after detonation.

The fireball, beginning its existence in the very process of disintegration of the bomb, was clearly in view during the first 2 sec. Then, for 2 or 4 sec, it was partially or wholly obscured from view by the condensation cloud. At about 5 to 8 sec after Mike Hour it came into view again. It grew, rose, and -- by 10 to 20 sec after Mike Hour -- had lost itself in the rapidly rising mushroom.

The condensation cloud, sometimes called the Wilson Cloud, formed immediately after the shock wave outstripped the fireball (i.e., at about 1.5 or 2 sec after Mike Hour) and grew rapidly. It was highly luminous at first because of the fireball located at its center. By 5 sec after Mike Hour the condensation cloud had become toroidal. By 10 to 15 sec after Mike Hour it was broken up; fragments disappeared rapidly, due to evaporation.

The mushroom top evolved from the fireball and from the air above the fireball; it assumed its characteristic mushroom appearance within 20 sec after Mike Hour. Within one minute it had reached an altitude of 13,000 ft, and it eventually reached a height of 40,000 ft. When the mushroom top reached approximately 18,000 ft, (i.e., after approximately 2 min) it was sheathed in a thin cap composed, perhaps, of ice crystals. No rain fell. The cloud drifted with the wind, lost its mushroom shape and was lost to the sight of the observers off Bikini within approximately 1 hr.

All but an insignificant fraction of the fission products rose in the mushroom, whose radioactivity was still detectable at a distance of 70 mi.

Within a few seconds of the passage of the suction wave past a given target ship, a black cloud, often larger than the ship itself, could be seen above the ship. (The cloud is believed to have been composed of soot and dirt shaken loose from — and sucked out of — the stacks and other superstructure paraphernalia.)

Some fires were detected by observers.

Water waves were not discernible to observers.

The sound of the explosion did not reach the 20-mi-distant non-target vessels for nearly 2 min; it was barely audible.

12.002 Total Energy Release.

The best value for the total amount of energy released by the explosion is 8.0×10^{20} ergs, which is equal to the total amount of energy released in the explosion of 19.1 kilotons of TNT. This figure is based on the radio-chemical method described in Chap. 5. (Source: Oral statement 25 Oct 46 by Technical Director.) The probable error is: 10 percent. (Source: Ref. 300-22, p.4)

12.003 Partial Energy Release.

Collateral values of equivalent-TNT-tonnage are given below. They are not ordinarily strictly indicative of the total amount of energy released, but are indicative only of that portion of the energy manifest in the shock wave, or some other phenomenon. Their significance is discussed in Chap. 5 and also in Refs. 500, 300-4, and 300-18.

Parameter Measured	Types of Gage Used	Equivalent-TNT-Kilotons	Source (Ref.No.)
Pressure in air	Diaphragm strain	20	300-4
Pressure in air	Foil	21	300-4
Pressure in air	Can and Drum	20	300-4
Pressure in air	Airborne Condenser	17	300-4
Duration of positive pulse in air	De Juhasz	20	300-4

Wind Velocity	Pipe	20	300-4
Shock wave velocity	Chronograph recorder	21	300-4
Rate of increase in radius of fireball	O'Brien camera	21	300-4
Total optical radiation	Bolometer	40(very rough)	300-18

12.004 Utilization of Energy.

No data were available by 1 Nov 46 as to the utilization or apportioning of the energy among nuclear radiation, shock wave, column, gravity waves, and heat.

No more than 10 percent (or possibly 20 percent) of the energy went into potential energy of the column. (Source: Ref. 302)

Chapter 13

Damage to Vessels, Test A

Outline

Chapter 13

Damage to Vessels, Test A

13.001 Introduction.

This Chapter includes a brief, preliminary, and a highly tentative summary of the significant damage suffered by the principal target vessels in Test A. In no sense are the data final, nor are they necessarily representative of considered judgments by the Director of Ship Material.

Much more extensive summaries, of considerably increased reliability, are now in preparation by DSM, and will be available soon. These forthcoming summaries, here referred to as Ref. 450, will include also a number of monographs on such subjects as flooding, fire, welding, piping. In addition, they will present detailed tabulation of damage index numbers and charts showing damage as a function of distance. Final conclusions and evaluations of ship damage should be made only after consulting these reports.

The generalization included below should be regarded merely as interim estimates by the JTF-1 Technical Historian.

Considered first is damage to ships as wholes; then damage to hulls (exclusive of superstructures, masts, antennas, and stacks); then damage to superstructures; and so on. In nearly every instance, damage means: damage indicative of loss of military efficiency.

13.002 Loss of Military Efficiency.

Note: The term military efficiency as used in this Chapter refers only to the military efficiency of the vessels themselves, irrespective of crews.

A. Very Serious Loss of Military Efficiency.

1. Ships Sunk. Five ships were sunk in Test A. The ships were:

Vessel	Horizontal Distance from Zeropoint (yd)
GILLIAM (APA-57)	50
SAKAWA (ex-Jap CA)	420
CARLISLE (APA-69)	430
ANDERSON (DD-411)	600
LAMSON (DD-367)	760

2. Ships Immobilized. Six (non-sunk) ships were immobilized. They were located at ranges of 400 to 1000 yd from the actual Zeropoint. Their immobilization was ordinarily a result of damage to stacks and boilers. The ships were:

INDEPENDENCE (CVL-22)	560
NEVADA (BB-36)	615
ARKANSAS (BB-33)	620
PENSACOLA (CA-24)	710
SALT LAKE CITY (CA-25)	895
HUGHES (DD-410)	920

B. Serious Loss of Military Efficiency. Among the ships suffering short or long term serious loss of military efficiency were:

SKATE (SS-305)	400
YO-160	520
CRITTENDEN (APA-77)	595
ARDC-13	825
DAWSON (APA-79)	855
RHIND (DD-404)	1012
SARATOGA (CV-3)	2265
LST-52	1630

C. Moderate Loss of Military Efficiency. Among the ships suffering short or long term moderate loss of military efficiency were:

TALBOT (DD-390)	1165
BARROW (APA-61)	1335
PENNSYLVANIA (BB-38)	1540
NEW YORK (BB-34)	1545

D. Slight Loss of Military Efficiency. Damage to electronic equipment caused slight loss of military efficiency as far out as approximately 1800 yd.

E. Range versus Loss of Military Efficiency. The ranges given below for various specified degrees of loss of military efficiency are such that, at a given horizontal range, it is probable

(probability greater than 50 percent) that a surface ship of unspecified type and orientation will suffer -- at least temporarily -- the indicated degrees of loss of military efficiency.

Extent of (at least temporary) Loss of Military Efficiency	Range (yd)
Very serious	900
Very serious (but disregarding boiler damage)	600
Serious	1000
Moderate	1300
Slight	1500

13.003 Damage to Hulls.

A. Introduction. This section discusses damage to hulls, here considered to include decks, sides, and bottoms of vessels. (Damage to superstructure, i.e., structure above the weather deck, is treated in Sec. 13.004; damage to masts is considered in Sec. 13.005 and damage to stacks in Sec. 13.007.) In most cases damage to hulls of surviving vessels was light and was not accompanied by flooding. Damage to the hulls of the sunken vessels was severe; it consisted usually of tears in the side shell plating and, of course, flooding.

B. Description of Damage.

1. Battleships. NEVADA (615 yd), battleship closest to the actual Zeropoint, received only minor hull damage; no flooding occurred. As to battleships in general, main decks were dished at distances as great as 780 yd, and at 1540 yd there was no significant hull damage.

2. Cruisers. Severe hull damage (including a tear along the centerline at the stern) caused the sinking of the Japanese light cruiser, SAKAWA (420 yd). (SAKAWA was of considerably lighter construction than PENSACOLA or SALT LAKE CITY and her hull damage cannot be compared with damage to the U. S. Cruiser.) The light aircraft carrier INDEPENDENCE (560 yd), suffered severe hull damage; her hull was blown in and there was buckling of bulkheads, reducing watertightness. (INDEPENDENCE had a modern cruiser hull which, although lighter than the riveted hulls of PENSACOLA and SALT LAKE CITY, was partly of welded construction.) PENSACOLA (710 yd) suffered severe dishing of deck structure. Dishing of the same order but less

serious occurred on SALT LAKE CITY (895 yd). PRINZ EUGEN (of heavier and more modern construction than PENSACOLA or SALT LAKE CITY) experienced practically no hull damage at 1195 yd.

3. Destroyers. ANDERSON (600 yd) sustained severe hull damage causing sinking (probable hole in plating on port side). Similarly, LAMSON (760 yd) sank (probable hole in starboard side). HUGHES (920 yd) survived without flooding, suffering some dishing and bulging of her main deck. RHIND (1010 yd), TALBOT (1165 yd), STACK (1330 yd), and WILSON (1480 yd) had very minor dishing of their hulls. MUSTIN (2145 yd) was not damaged.

4. Submarines. SKATE (400 yd) had her outer hull badly stripped and crumpled; her pressure hull suffered substantially no damage and did not experience flooding. APOGON (940 yd) was undamaged.

5. Attack Transports. GILLIAM (45 yd), APA closest to the actual Zeropoint, sank within one minute; she was badly ruptured, crumpled, and twisted almost beyond recognition. CARLISLE (430 yd) sank within 40 min; her side shell plating contained two very long breaks and severe dishing also. CRITTENDEN (bow-on, at 595 yd), surviving APA nearest to the actual Zeropoint, suffered severe dishing and deflection of deck; she was not flooded. Her bow-on orientation may have saved her from being sunk.

6. Aircraft Carriers. Damage to the sides and bottom of INDEPENDENCE (560 yd) has been discussed in the paragraph on cruisers, since her hull was very similar to that of a light cruiser. SARATOGA (2265 yd) was not damaged.

7. Other Vessels. YO-160 (520 yd) had its concrete deck spalled, with bent reinforcing bars exposed in numerous places. There was no flooding. LST-52 (1530 yd) suffered light dishing of starboard shell plating. ARDC-13 (825 yd) was cracked just below the waterline permitting seepage into two compartments.

C. Loss of Military Efficiency.

1. Battleships. Battleships suffered no loss of military efficiency due to hull damage.

2. Cruisers. Japanese cruiser SAKAWA (420 yd) sank in 25 hr due to hull damage (the ship's force, if uninjured, could possibly have saved her). INDEPENDENCE (light cruiser hull, 560 yd) suffered serious loss of military efficiency due to loss of watertightness above the waterline; she would have suffered progressive flooding in heavy seas. PENSACOLA (710 yd) suffered serious loss of military efficiency due to loss of watertightness above the second deck, and

her longitudinal structural strength was slightly impaired. She could have been made sufficiently operable by ships' force to return to port for repair, but would not have been an effective fighting unit without such repair. SALT LAKE CITY (895 yd) suffered some hull damage above her second deck.

3. Destroyers. Destroyers ANDERSON (600 yd) and LAMSON (760 yd) sank as the result of hull damage. (ANDERSON sank in 8 min; LAMSON sank in approximately 5 hr.) HUGHES (920 yd) suffered slight loss of military efficiency.

4. Submarines. There was no impairment of military efficiency of submarines due to damage to pressure hull.

5. Attack Transports. GILLIAM (45 yd) and CARLISLE (430 yd) sank. CRITTENDEN (595 yd) suffered serious loss of military efficiency and would have been unable to operate as a transport without extensive repairs to her hull.

D. Distance versus Damage Relationship. The Test-A distance versus hull damage data are presented in Table 13.1. The distances given are (as elsewhere in this Chapter) horizontal distances in yards from the projected actual Zeropoint to the nearest part of the vessel. In most cases the distances figure given represents the greatest radius* at which damage of indicated severity actually occurred to target vessels on A-Day. In the "Negligible Damage" column, however, the value given for each type of vessel is the range of that vessel (suffering negligible damage) which was nearest the Zeropoint. Similarly the "Nearest Surviving Ship" column gives for each type of ship the range of that (surviving) ship which was nearest the Zeropoint. In using the Table, it is convenient to bear this rule in mind: when comparing vulnerability of ships of different type (with respect to damage of specified type and severity), or when comparing vulnerability of different parts of a ship, higher numbers indicate greater vulnerability.

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* If the "sample" of ships had been greater, instances would presumably have occurred where even greater ranges could have been found for damage of specified type. On the other hand, we may now have instances where ships at lesser ranges did not suffer damage of the indicated severity. Thus the ranges here presented are not intended to be ranges for which the probability value equals 50 percent or any other percentage; they are merely observed greatest ranges. On the other hand, they are probably fairly close, in many cases, to "probability-equals-50 percent" ranges given in other sections.

E. Ship Type versus Damage Relationship. It is tentatively suggested that hull vulnerability of principal types of target ships increased in the following order: submarines (least vulnerable); battleships; and attack transports and destroyers (most vulnerable). Attack transports might have proved more vulnerable had it not been for the fact that CRITTENDEN, at 595 yd, happened to be almost exactly bow-on, and survived. The most representative range for (probable) major hull damage is of the order of 600 yd.

F. Engineering Consequences of Damage. In most cases where the hull was breached, flooding occurred, causing sinking. Damage to hulls not involving flooding had no appreciable effect on the operation of propulsion machinery. ARDC-13 (825 yd), a concrete drydock, suffered some flooding due to cracks to her hull; her standard pumps (not actually installed prior to the test) could have controlled the flooding readily.

G. Mechanism of Producing Damage. In all or nearly all cases hull damage was attributable to the pressure wave in air.

13.004 Damage to Superstructure.

(Mast damage is discussed in Sec. 13.005 and stack damage is discussed in Sec. 13.007.)

A. Introduction. The superstructure of the target ships were especially vulnerable, i.e., to the air burst.

Damage appeared typically in the form of dishing or other distortion. INDEPENDENCE (560 yd) had large holes blown in the sides enclosing her hangar deck. Plating of 10-lb weight (1/4 in. thick) or heavier in the superstructure of ships, at 600 yd or more, did not suffer much deformation.

B. Description of Damage.

1. Battleships. All of the battleships received superstructure damage ranging from extensive distortion at 620 yd, to heavy dishing at 780 yd, and light dishing at 1550 yd. There were no battleships beyond this range.

2. Cruisers. Japanese light cruiser SAKAWA (420 yd) had her superstructure badly crushed. Both U. S. cruisers received superstructure damage. PENSACOLA (710 yd) suffered extensive distortion whereas SALT LAKE CITY (895 yd) suffered heavy dishing. There were no U. S. cruisers beyond this distance. German heavy cruiser PRINZ EUGEN (1195 yd) suffered light dishing of her superstructure.

TABLE 13.1. GREATEST RANGE AT WHICH DAMAGE OF INDICATED SEVERITY WAS PRODUCED IN TEST A
(Range is horizontal distance in yards from projected zeropoint to nearest part of ship)

Ship Type and Distances	Innermost Surviving Ship	Sunk	HULL (DECKS, SIDES, BOTTOM)				SUPERSTRUCTURE				Masts and Antennae		Boilers		Stacks or Uptakes		Miscellaneous Machinery
			Major Damage	Moderate Damage	Minor Damage	Negligible Damage	Major Damage	Moderate Damage	Minor Damage	Negligible Damage	Major Damage	Minor Damage	Major or Moderate Damage	Minor or No Damage	Major or Moderate Damage	Minor or No Damage	Major or Moderate Damage
Battleships 615, 620, 780, 1540, 1550	615 (NEVADA)	No Cases	No Cases	No Cases	780 (NAGATO)	1540 (PENN.)	620 (ARKANSAS)	780 (NAGATO)	1550 (NEW YORK)	No Cases	780 (NAGATO)	1540 (PENN.)	1550 (NEW YORK)	No Cases	1550 (NEW YORK)	No Cases	620 (airplane cranes)
Cruisers (U.S.) 560, 710, 895	560 (INDEPENDENCE)	No Cases	560 (INDEP.)	895 (S.L.C.)	No Cases	No Cases	710 (PENSACOLA)	895 (S.L.C.)	No Cases	No Cases	895 (S.L.C.)	No Cases	895 (S.L.C.)	No Cases	895 (S.L.C.)	No Cases	610 — (airplane crane)
Cruisers (Foreign) 420, 1190	1190 (EUGEN)	420 (SAKAWA)	420 (SAKAWA)	No Cases	No Cases	1190 (EUGEN)	420 (SAKAWA)	No Cases	1190 (EUGEN)	No Cases	1190 (EUGEN)	No Cases	420 (SAKAWA)	1190 (EUGEN)	420 (SAKAWA)	1190 (EUGEN)	Less Than 1190
Destroyers 600, 760, 920 1010, 1165, 1330, 1480, 2150	920 (HUGHES)	760 (LAMSON)	760 (LAMSON)	920 (HUGHES)	1480 (WILSON)	2150 (MUSTIN)	760 (LAMSON)	1010 (RHIND)	1480 (WILSON)	2150 (MUSTIN)	1165 (TALBOT)	1480 (WILSON)	1010 (RHIND)	1165 (TALBOT)	1165 (TALBOT)	1480 (WILSON)	Less Than (HUGHES) 920
Submarines 400, 940	400 (SKATE)	No Cases	No Cases	No Cases	400 (SKATE)	940 (APOGON)	400 (SKATE)	No Cases	No Cases	940 (APOGON)	400 (SKATE)	940 (APOGON)	No Cases	No Cases	No Cases	No Cases	400 (SKATE Bow Buoyancy Vent Valves)
Aircraft Carrier (Light) 560	560 (INDEPENDENCE)	No Cases	Same as U.S. Cruisers				560 (INDEP.)	No Cases	No Cases	No Cases	560 (INDEP.)	No Cases	No Cases	No Cases	560 (INDEP.)	No Cases	560 (elevators swept overboard; catapult machinery inoperable)
Aircraft Carrier (Heavy) 2260	2260 (SARATOGA)	No Cases	Same as Battleships				No Cases	No Cases	No Cases	2000	No Cases	No Cases	No Cases	No Cases	No Cases	No Cases	2260 (elevator jammed)
Attack Transports 50, 430, 595, 855, 1005, 1180, 1290, 1335, 1575, 1675, 1760	595 (CRITTENDEN)	430 (CARLISLE)	595 (CRITTENDEN)	855 (DAWSON)	1575 (BRISCOE)	1675 (CARTERET)	595 (CRITTENDEN)	1005 (BRULE)	1575 (BRISCOE)	1675 (CARTERET)	1180 (BANNER)	1675 (CARTERET)	430 (CARLISLE)	855 (DAWSON)	595 (CRITTENDEN)	855 (DAWSON)	1005 (while Davits inoperable)
Explanation of Column Headings			Flooding or Severe Buckling of Plates	Heavy Dishing	Light Dishing	Distance of Nearest Ship Suffering Negligible Damage	Demolished or Extensive Distortion	Heavy Dishing	Light Dishing	Distance of Nearest Ship Suffering Negligible Damage.	Damage Rendering Antennae and Radar Inoperable	Minor Damage	Loss of Boiler Power	Minor or no Damage	Impairment of Boiler Operation	Minor or no Damage	Machinery Damage Impairing Military Efficiency

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3. Destroyers. Destroyers, being lightly constructed, suffered much superstructure damage. The extensive distortion zone extended out to 760 yd, heavy dishing to 1010 yd and light dishing was experienced at 1480 yd.

4. Submarines. The superstructure on SKATE (400 yd) was very extensively damaged -- in fact, badly stripped and crumpled. APOGON (940 yd) received no superstructure damage.

5. Aircraft Carriers. The superstructure on INDEPENDENCE (560 yd) was extensively damaged. Her flight deck was badly warped and buckled, and the sides enclosing her hangar deck were blown through. SARATOGA (2265 yd) received no appreciable superstructure damage.

6. Attack Transports. Damage to APA superstructure ranged from extensive distortion (to bow-on CRITTENDEN) at 595 yd to heavy dishing at 1005 yd and very light dishing as far out as 1290 yd.

7. Other Vessels. Extensive damage to the superstructure of concrete oil barge YO-160 was experienced at 520 yd.

C. Loss of Military Efficiency.*

1. Introduction. There were no cases in which superstructure damage per se put ships out of action. However, extensive superstructure damage in many cases impaired the military efficiency of the ship. Damage to superstructure often caused loss of watertightness, malalignment of gun batteries, and damage to radar and communication antennas.

2. Battleships. Damage to light superstructure plating on NEVADA (615 yd) caused damage to fire control antennas and moderate loss of military efficiency. (See Sec. 13.005 on Masts.) No other battleships suffered appreciable loss of military efficiency due to superstructure damage.

3. Cruisers. PENSACOLA (710 yd) suffered slight loss of seaworthiness due to failure of topside doors and hatches; SALT LAKE CITY (895 yd) also suffered some superstructure damage. No other surviving cruisers suffered appreciable loss of military efficiency due to superstructure damage.

4. Destroyers. There was no very notable loss of military efficiency of surviving destroyers due to superstructure damage. (See however, Sec. 13.005 on Damage to Masts and Sec. 13.007 on Damage to Stacks and Uptakes.)

5. Submarines. Extensive superstructure damage to SKATE

(400 yd) seriously impaired her military efficiency. APOGON (940 yd) suffered no significant loss of military efficiency due to superstructure damage.

6. Aircraft Carriers. Flight deck of INDEPENDENCE (560 yd) was put out of commission involving complete loss of military efficiency. Hangar deck also was wrecked, sides were blown through, and a fire in the stern added to the serious loss of military efficiency. The superstructure of SARATOGA (2265 yd) was undamaged.

7. Attack Transports. Superstructure damage probably did not seriously impair the military efficiency of the surviving APA's.

8. Other Vessels. There was no loss of the military efficiency of the oil barges and concrete drydock due to superstructure damage.

D. Distance versus Damage Relationship. The distance versus damage data for superstructure damage are presented in Table 13.1.

E. Ship Type versus Damage Relationship. Superstructure vulnerability appears to be approximately the same for the principal types of target ships. The approximate maximum radii for superstructure damage of specified severity were: for major damage, 700 yd; for moderate damage, 1000 yd; and for minor damage, 1500 yd. Not included in this comparison are submarines, since there was only one instance of superstructure damage to this type of ship. Destroyer superstructures were somewhat more vulnerable than the rest.

13.005 Damage to Masts.

A. Introduction. Damage to masts was especially serious in Test A because of the resulting damage to radio and radar antennas connected to the masts.

B. Description of Damage. Damage to masts was evidenced by breakage or bending accompanied by damage to communication or radar antennas.

C. Loss of Military Efficiency by Damage to Masts.

1. Introduction. The chief loss of military efficiency resulting from mast damage was failure of search radar, fire control radar, and radio. In cases of radar antenna damage, repairs could not be made by the ship's force at sea.

2. Battleships. All the antennas on NEVADA (615 yd) were

blown down due to mast failure; this caused serious loss of military efficiency. Similarly, ARKANSAS (620 yd) and NAGATO (780 yd) suffered complete loss of antennas and thus suffered serious loss of military efficiency. There was slight reduction of military efficiency on PENNSYLVANIA (1540 yd) which suffered minor antenna damage due to mast failure; NEW YORK (1545 yd) experienced no antenna damage.

3. Cruisers. PENSACOLA (710 yd), SALT LAKE CITY (895 yd), and PRINZ EUGEN (1195 yd) suffered serious reduction in military efficiency due to mast failure.

4. Destroyers. The military efficiency of destroyers out to 1160 yd was seriously impaired due to mast failure.

5. Submarines. SKATE (400 yd) suffered serious loss of military efficiency due to mast damage and complete loss of antennas.

6. Aircraft Carriers. INDEPENDENCE (560 yd) suffered serious loss of military efficiency due to mast damage and complete loss of antennas.

7. Attack Transports. APA's out to 1005 yd suffered moderate loss of military efficiency due to mast and antenna damage.

D. Distance versus Damage Relationship. The distance versus damage data for mast damage are presented in Table 13.1. Only mast damage leading to damage to antennas is recorded.

E. Ship Type versus Damage Relationship. Mast damage occurred on ships of all types. In general, damage occurred (minor in some cases) out to 1500 yd. The approximate maximum radius for major mast damage was 1100 yd for nearly all types of ships.

F. Engineering Consequences of Damage. As indicated in a previous paragraph, the engineering consequence of mast damage was failure of radar and radio antennas, rendering radar and radio equipment inoperable.

G. Mechanism of Producing Damage. Mast damage was caused by the pressure wave in air.

13.006 Damage to Boilers.

Boiler damage in Test A was limited principally to casings, brickwork, oil burners, smoke periscopes, smoke pipes, and uptakes. In general, external fittings and boiler pressure parts suffered no

damage. In all cases of boiler damage mentioned in this Section, there was loss of boiler power.

B. Description of Damage.

1. Battleships. All U. S. battleships suffered major boiler damage. NEVADA (615 yd) had side-casing panels on all six boilers blown out. ARKANSAS (620 yd) suffered damage to boiler casings and minor damage to brickwork. PENNSYLVANIA's boilers were inoperable (1540 yd) due to bulging of boiler side-casing panels. NEW YORK (1545 yd) had its boiler casings partially blown off. Boilers on NAGATO (780 yd) were undamaged.

2. Cruisers. Both U. S. cruisers suffered major boiler damage. PENSACOLA (710 yd) suffered damage to boiler casings on all eight of her boilers. SALT LAKE CITY (895 yd) suffered damage to boiler casings as well as to brickwork. No boiler on either of these cruisers could have been used without extensive repair. INDEPENDENCE (560 yd) experienced negligible damage to her boiler casings. She could have steamed after moderate repairs.

3. Destroyers. HUGHES (920 yd) suffered bulging of boiler casings. Her boilers could not have been operated without major repairs. There was damage to boiler brickwork on RHIND (1010 yd) but boiler casings were tight. Two of her boilers were in satisfactory condition for steaming. No other destroyers suffered significant boiler damage.

4. Attack Transports. CRITTENDEN (595 yd), surviving APA nearest Zeropoint, had the boiler casing of one boiler split. Both boilers were in operable condition. No other surviving APA's suffered significant boiler damage.

C. Loss of Military Efficiency.

1. Introduction. In general, boiler damage resulted in loss of power accompanied by reduced speed and impaired operation of ordnance and machinery, involving serious loss of military efficiency.

2. Battleships. The military efficiency of NEVADA (615 yd) was very seriously reduced (to 10 percent or less) by loss of power due to boiler damage. As this ship had steam steering, this also was out of commission. Temporary repairs by ship's force could be made in 12 to 24 hr to enable her to steam at a very slow speed. ARKANSAS (620 yd) would have been dead in the water due to boiler damage until temporary repairs had been effected (5 to 10 hr). Her military efficiency was very seriously reduced. PENNSYLVANIA (1540 yd) would have lost all motive power for a short interval after which she could have steamed at greatly reduced speed with serious reduction

in military efficiency. NEW YORK (1545 yd) suffered moderate loss of military efficiency due to boiler damage which would have prevented full power operation for 12 hr.

3. Cruisers. INDEPENDENCE (cruiser hull, 560 yd) suffered no loss of military efficiency due to boiler damage. (However, damage to stacks and uptakes would have immobilized her for a day or more. See Sec. 13.005.) PENSACOLA (710 yd) was immobilized due to boiler damage: her military efficiency was seriously reduced (to 5 percent or less). SALT LAKE CITY (895 yd) would have been immobilized for 72 hr or more, with very serious reduction of military efficiency. PRINZ EUGEN (1195 yd) had no loss of military efficiency as the result of boiler damage.

4. Destroyers. Destroyers out to 1010 yd suffered very serious loss of military efficiency due to loss of power resulting from boiler damage. (Power on destroyers out to 1165 yd would have been reduced due to stack and uptake damage.)

5. Attack Transports. CRITTENDEN (595 yd) was the only surviving APA to suffer loss of military efficiency due to boiler damage. Her military efficiency was moderately impaired.

D. Distance versus Damage Relationship. The distance versus damage data for boiler damage are presented in Table 13.1. The "Major Damage" column gives greatest radii at which boiler damage occurred and resulted in loss of power.

E. Ship Type versus Damage Relationship. Boilers on battleships and U. S. cruisers of older designs were found to be especially vulnerable to damage. Boiler damage occurred on battleships out to 1550 yd and on the outermost U. S. cruiser at 895 yd. The Japanese battleship NAGATO (780 yd) and the German heavy cruiser PRINZ EUGEN (1195 yd) did not receive boiler damage. Significantly, the boilers on the modern carrier INDEPENDENCE (light cruiser hull) were undamaged at 560 yd, although this ship suffered severe stack damage. Boilers on destroyers were not appreciably damaged beyond 1010 yd, and boilers on attack transports were not damaged beyond 430 yd.

The difference in vulnerability of boilers on ships of different types is believed to be due partly to difference in stack construction, and partly to differences in stack height, protection, and kind of metal used. Stacks in older ships were in many instances riveted whereas the stacks on the destroyers and attack transports were often of welded construction. See Sec. 13.007 for discussion of stack and uptake damage.

F. Engineering Consequences of Damage. Boiler damage was accompanied by loss of power for propulsion and for operation of

ship's machinery and ordnance.

G. Mechanism of Producing Damage. Boiler damage was often caused by air pressure going down stacks. Where the stack was swept away or torn, the pressure wave probably reached the boilers directly through the uptakes.

13.007 Damage to Stacks and Uptakes.

A. Introduction. Damage to stacks and uptakes was significant because of the effect on boiler operation. In each case of stack or uptake damage discussed in this Section, there was loss of boiler power regardless of whether or not there was actual damage to the boiler itself.

B. Description of Damage.

1. Battleships. NEVADA (615 yd) had her outer stack dished and distorted and the top of her inner stack carried away. Uptakes below her main decks were carried away. ARKANSAS (620 yd) had her stack completely demolished. No other battleships suffered stack damage.

2. Cruisers. All four stacks on INDEPENDENCE (light cruiser hull, 560 yd) were demolished. PENSACOLA (710 yd) and SALT LAKE CITY (895 yd) suffered major stack damage. German heavy cruiser PRINZ EUGEN (1195 yd) did not suffer stack damage.

3. Destroyers. Destroyers suffered serious stack damage out to 1165 yd.

4. Attack Transports. APA stacks were seriously damaged only out to 595 yd.

C. Loss of Military Efficiency.

1. Introduction. In all cases of major stack damage there was loss of boiler power accompanied by reduced speed and impaired operation of ordnance and machinery, involving loss of military efficiency. In general, temporary stack repairs could be made by ship's force at sea.

2. Battleships. All U. S. battleships suffered serious stack damage which would have impaired boiler operation independently of whether the boilers themselves had been damaged. (Actually, boilers on all battleships were damaged.) Their military efficiency was very seriously reduced due to stack damage.

3. Cruisers. INDEPENDENCE (light cruiser hull, 560 yd) suffered very serious loss of military efficiency due to stack and uptake damage. (She would have been immobilized for a day or more. However, her biolers were undamaged. Both PENSACOLA (710 yd) and SALT LAKE CITY (895 yd) would have suffered very serious loss of military efficiency due to stack damage. Both PENSACOLA and SALT LAKE CITY suffered boiler damage.)

4. Destroyers. Whereas boiler damage on destroyers extended only to 1010 yd, stack and uptake damage very seriously reduced their military efficiency and would have prevented full boiler power on destroyers out to 1165 yd.

5. Attack Transports. Stack damage to CRITTENDEN (595 yd) reduced boiler power and very seriously impaired her military efficiency. (CRITTENDEN's boilers were also damaged at this distance.)

D. Distance versus Damage Relationship. The distance versus damage data for stack damage are presented in Table 13.1. In all cases of major or moderate stack damage there was loss of boiler operation, but not necessarily boiler damage.

E. Ship Type versus Damage Relationship. It is tentatively suggested that stack vulnerability increased in the following order: attack transports (least vulnerable), battleships, cruisers, destroyers (most vulnerable). However, the differences may in some cases be due to relatively extraneous factors.

F. Engineering Consequences of Damage. Serious stack damage impaired boiler operation.

G. Mechanism of Producing Damage. Stack damage was due to the pressure wave in air.

13.008 Damage to Miscellaneous Machinery.

A. Introduction. With the exception of damage to boilers, uptakes, and stacks, damage to machinery on surviving vessels was confined to topside deck auxiliaries.

B. Description of Damage.

1. Battleships. Both the NEVADA (615 yd) and ARKANSAS (620 yd) suffered damage to airplane cranes.

2. Cruisers. The airplane crane on PENSACOLA (710 yd) was rendered inoperative.

3. Destroyers. There was no significant damage to destroyer auxiliary machinery.

4. Aircraft Carriers. INDEPENDENCE (560 yd) lost forward and after elevator platforms. SARATOGA (2265 yd) suffered temporary jamming of her only elevator for airplanes.

5. Attack Transports. Boat davits on CRITTENDEN (595 yd) and DAWSON (855 yd) were rendered inoperative.

C. Loss of Military Efficiency.

1. Battleships and Cruisers. NEVADA, ARKANSAS, and PENSACOLA were unable to launch their planes. This caused a slight loss of military efficiency.

2. Destroyers. There was no significant loss of military efficiency.

3. Aircraft Carriers. Neither INDEPENDENCE nor SARATOGA could operate as carriers, both losing use of elevators. (This constituted very serious immediate loss of military efficiency; however, SARATOGA's elevator was readily repairable.)

4. Attack Transports. Failure of boat davits on CRITTENDEN and DAWSON greatly impaired efficiency in unloading troops. (This constituted serious loss of military efficiency.)

D. Distance versus Damage Relationship. The distance versus damage data for damage to auxiliary machinery are presented in Table 13.1. Only damage to vital auxiliary machinery is considered.

E. Engineering Consequences of Damage. Failure of airplane cranes and elevators temporarily prevented raising or lowering of aircraft. Failure of boat davits prevented raising or lowering of small boats.

F. Mechanism of Producing Damage. Damage to auxiliary machinery was caused by the pressure wave in air.

13.009 Damage to Electrical Equipment.

Exposed electrical equipment and instruments suffered serious damage within a radius of approximately 900 yd. Interior electrical equipment suffered little or no damage other than damage associated with distortion of supporting structure or with secondary fires. In general, damage to electrical equipment did not cause serious loss of

military efficiency.

13.010 Damage to Ordnance Equipment.

The air burst did very little serious damage to ordnance equipment in the target vessels. This is not surprising since ordnance gear is, of course, designed to withstand gun blast.

Because of boiler damage major power-operated ordnance equipment was inoperative on NEVADA (615 yd), ARKANSAS (620 yd), INDEPENDENCE (560 yd), PENSACOLA (710 yd), SALT LAKE CITY (895 yd), and HUGHES (920 yd). RHIND (1010 yd) would probably have been adversely affected also, because of interference by smoke as a result of loss of her stacks.

In general damage to radar antennas (see Sec. 13.005) greatly reduced the accuracy of fire control systems within 1000 yd of the Zeropoint.

Modern rangefinders withstood the explosion with no internal damage. Rangekeepers suffered light damage. Ammunition withstood the heat and blast without change. Torpedoes, mines, and depth charges were not detonated. Twelve torpedo warheads on INDEPENDENCE (560 yd) burned. External heat on the torpedo air flasks caused explosion of some of the flasks.

13.011 Damage to Electronic Equipment.

Electronic equipment sustained major damage on 11 vessels and minor damage on 17 additional vessels. Damage to antennas of radio and radar equipment accounted for over 90 percent of the equipment rendered inoperative. (See Sec. 13.005.) Vacuum tubes and other delicate components protected by enclosures generally remained undamaged. The pressure wave in air was responsible for the majority of damage.

Major damage was confined to an area within 1000 yd of the Zeropoint. Minor damage occurred at ranges between 1000 yd and 1500 yd. Electronic equipment on ships beyond 2500 yd was in most cases undamaged.

13.012 Damage from Fires.

Flash heat scorching was apparent on surfaces normal to the blast up to a distance of about 3700 yd. Many fires started in jute and manila cordage. The burlap wrapping of Army Quartermaster material ignited in some instances. There was considerable evidence that many incipient fires within a radius of 1500 yd of the Zeropoint were extinguished by the air pressure wave immediately following the flash.

There were no oil fires either in the water or in target ships (except on SAKAWA). In general, damage from fires did not cause serious loss of military efficiency, except in the case of the INDEPENDENCE.

13.013 Damage from Ammunition Explosions.

There was no evidence of loss of ships or serious damage to ships through ammunition explosions. However, there probably was an explosion on ANDERSON (600 yd).

13.014 Relationship Between Ship Orientation and Damage.

The relationship between ship orientation and damage has not yet been evaluated. Unfortunately, there were few cases where damaged ships located at equal distances from the actual Zeropoint had contrasting orientations.

Chapter 14

Other Damage, Test A

Outline

Section

Chapter 14

Other Damage, Test A

14.001 Introduction.

Damage to material and equipment which are more or less standard on Naval vessels has been discussed in the previous chapter. The present chapter describes the damage to special test equipment exposed on the target vessels. More detailed information may be obtained from Ref. 420-2 and 410-7.

14.002 Damage to Vehicles, Guns, and Searchlights.

Tanks and guns suffered no impairment of operational efficiency at or beyond 600 yd. Inspection plate fastenings failed at ranges as great as 1500 yd. Unarmored vehicles, searchlights, and airplane structures were severely damaged at ranges up to 1200 yd and suffered minor damage at ranges from 1200 to 2500 yd.

14.003 Damage to Electronic Equipment.

Electronic equipment and instruments were seriously damaged at ranges up to 1200 yd and slightly damaged at ranges of 1200 to 2500 yd. Small, compact equipment was superior to large units in blast resistance.

14.004 Damage to Special Ammunition and Pyrotechnics.

Packaged ammunition remained undamaged at distances greater than 1000 yd. At 1000 yd pyrotechnics in thin cases but otherwise unshielded were unaffected. Some exposed items, such as wrapped propelling charges and mortar powder increments in plastic casings, were destroyed at distances up to 2100 yd.

14.005 Damage to Food, Clothing, Etc.

Baled and packaged clothing was damaged, primarily by fire, at

distances up to 2000 yd. Certain insecticides, soaps, powders, and solutions retained appreciable amounts of radioactivity over a relatively long period of time. Nonperishable packaged food at 500 yd was cleared for consumption by four days after A-Day.

14.006 Damage to Rubber Materials.

Dense and thick rubber objects such as pneumatic tires and electrical cables were undamaged (except for superficial scorching) at and beyond 600 yd. Thin rubber coatings and objects of sponge rubber were charred at a distance of 600 yd.

14.007 Damage to Plastics.

Plastics were damaged at distances as great as 3000 yd. All kinds of plastics were highly susceptible to heat flash, which produced fusing. Laminated panels of glass and metal separated because of breakdown of the plastic-bonding compound.

14.008 Damage to Surfaces.

Thin surface layers of paper or paint were superficially scorched at 600 yd, but the general relationship between scorching and distance is not yet clear. Ranges of scorching and blistering of paint were irregular, depending on composition, color, and method of application and also (probably) on the extent of thermal radiation screening by steam or fog suddenly produced just above the surface of the Lagoon. Baked paint on Army equipment withstood heat much better than the flat paint on decks and bulkheads of ships.

14.009 Metallurgical Damage.

Radiation caused no perceptible metallurgical damage.

Chapter 15

Injury to Animals, and Plants, Test A

Outline

Chapter 15

Injury to Animals and Plants, Test A

15.001 Introduction.

Estimates and generalizations presented below, although very rough, are believed to be qualitatively accurate. The majority of the estimates and generalizations have been made by the JTF-1 Technical Historian, based on information contained in Ref. 410-5 and additional information obtained informally from the DSM Naval Medical Research Section and the 013 Radioactivity Section.

It is to be borne in mind that predictions as to ranges at which personnel would be injured are not necessarily based on data on injury to test animals, but may be based on measured values of pressure, gamma radiation, etc., and on previously determined values of lethal dosage.

15.002 Animal Census.

Presented below are the salient statistics on animals used in the Test.

Type of Animal	Number Exposed	Number Recovered Alive	Number Having Died since Returning to the BURLESON	Number Killed for Study	Number Alive on 25 Nov 46
Goats	176	153	26	12	115
Pigs	147	136	32	18	86
Rats	3130	2511	725	321	1465
Guinea Pigs	57	55	55	0	0
Mice	109	108	*	*	*

* Mice were exposed at considerable distances from the Zeropoint in order to provide data as to results of exposure to sub-lethal dosages of gamma radiation.

15.003 Dependence of Mortality on Range.

Presented below are the JTF-1 Technical Historian's estimates of mortality percentages:

Type of Animal	Range (yd)	Percentage of Animals of Indicated Type Which Had Died by 9 Aug 46 as a Direct Result of Blast and Radiation
Pigs	Less than 1000	50 ± 10
	1000 to 2000	15 ± 5
	More than 2000	15 ± 10
Goats	Less than 1000	85 ± 10
	1000 to 2000	30 ± 25
	More than 2000	5 ± 5
Rats	Less than 1000	75 ± 10
	1000 to 2000	25 ± 10
	More than 2000	15 ± 5

The significance of these figures is reduced by the fact that no account is taken of different distributions of the animals throughout their respective ships, or of different sample sizes; no analyses taking into account these factors were available by 15 Nov 46.

15.004 Relationship Between Mortality and Type of Animal.

No reliable conclusion can be drawn from the figures of the preceding section as to relative vulnerabilities of goats, pigs, and rats. However, long-range mortality figures (for period ending 5 Nov 46) indicate that pigs may be slightly more vulnerable to gamma radiation than goats or rats.

15.005 Degree of Protection of Animals.

As of 15 Nov 46 no shield-thickness data were available for the various animals exposed. Note: Lethal dosage of gamma radiation is usually taken to be 400 roentgens; lethal dosage of fast neutrons is 1×10^{11} fast neutrons per cm^2; for slow neutrons, the lethal dosage is 5×10^{11} slow neutrons per cm^2. Flash burn in animals at ranges greater than 600 yd was prevented by flash-burn cream or by fur.

15.006 Symptoms of Injury.

A. Symptoms Produced by Gamma Radiation. Animals receiving light doses of gamma radiation often appeared normal. Later some developed hemorrhagic patches beneath the oral mucous membrane. A few showed partial loss of hair and very few developed testicular atrophy.

Those animals more heavily exposed exhibited hyperirritability, muscular weakness, diarrhea, and increased rate of respiration. Some of these were moribund, with exaggeration of symptoms, bloody diarrhea and inability to stand.

B. Symptoms Produced by Air Blast. Symptoms of blast injury were: lung hemorrhages and contusions.

15.007 Radiological Dosage.

Since radiological dosage data are considered in detail in Chap. 17, only a summary of the most salient data are presented here.

At horizontal ranges of 0 to 1000 yd, topside dosage of gamma radiation was 1800 to over 8000 roentgens; inside heaviest turrets and below decks in very well-protected regions, the typical dosage was 1 to 50 roentgens. Neutron dosages were very high (lethal, ordinarily) within 500 yd, but were almost negligible beyond 700 yd. (Source: Ref. 300-20.)

Between 1000 and 2000 yd, topside dosage of gamma radiation varied from 28 to 1800 roentgens, while the dosage in well-protected regions was from 0 to 20 roentgens. The neutron dosage in this range was practically nonexistent.

Beyond 2000 yd, topside dosage of gamma radiation varied from 28 roentgens to zero; the dosage in well-protected regions was less than 1 roentgen.

15.008 Causes of Injury.

Air blast was the principal cause of injury leading to immediate (i.e., within the first hour) deaths and other immediate "loss of efficiency" of exposed animals; gamma radiation was second in importance. (Many of the animals killed by the air blast received lethal dosages of gamma radiation.)

Neutron radiation would have been important in protected locations

at ranges less than 650 yd, had there been any animals at such range.

Principal cause of delayed deaths and delayed "loss of efficiency" was gamma radiation.

15.009 Ranges of Injury of Specified Severity.

No estimate is included here as to the range at which it is probable (probability greater than 50 percent) that animals would be injured to a specified extent, since for various reasons any such estimates would be both inaccurate and of questionable significance. (See, however, Chap. 19, where estimates of ranges for probable injury to crews are presented.)

Chapter 16

Pressure Data, Test A

Outline

Chapter 16

Pressure Data, Test A

16.001 Introduction.

Detailed accounts of pressure produced by Bomb A are contained in Ref. 300, particularly Ref. 300-13.

16.002 Peak Pressure in Mach Stem Region.

Best values of peak pressure in the Mach Stem region, the air just above the surface of the water, are given below. (Source: Ref. 300-13, Fig. 2, curve "BuOrd")

Horizontal Distance from Projected Zeropoint (yd)	Peak Pressure (psi gage)
0	2000
360	110
400	87
500	53
600	36
700	25
800	18
900	13.5
1000	10.5
1100	8.7
1200	7.3
1300	6.2
1400	5.4
1500	4.8
1600	4.3
1700	4.0
1800	3.7
1900	3.3
2000	3.1
2500	2.3

According to Dr. W. G. Penney (Ref. 300-13), all best values (except those for distances less than 100 yd) have probable errors in the neighborhood of 5 percent. But according to JTF-1 Technical Historian, the data of Ref. 300-13 show that the best values ordinarily have probable errors of 10 to 20 percent, and values for distances less than 500 yd may have probable errors of 30 percent or more.

16.003 Peak Pressure Outside Mach Stem.

Peak-pressures values obtained at positions outside the Mach Stem region are given below: (Source: Ref. 300-22)

Altitude (ft)	Slant Range (yd)	Peak Pressure (psi gage)
26,800	11,100	0.168
26,800	11,800	0.178
26,800	13,300	0.150

By 1 Nov 46 no estimate of probable error had been made.

A peak pressure of 100 dynes/cm was measured at Kwajalein, approximately 218 nautical mi away. (Source: Ref. 300-19)

16.004 Duration of Positive Pressure Pulse at a Fixed Point in Air.

Duration of the positive pressure pulse at a fixed point in the Mach Stem region, just above the surface of the water, was as follows: (Source: Ref. 300-13)

Horizontal Distance from Projected Zeropoint (yd)	Duration of the Positive Pressure Pulse (sec)
360	0.42
500	0.46
750	0.59
1000	0.75
2000	1.0

By 1 Nov 46 no estimate of probable error had been made.

16.005 Shape of Pressure versus Time Curve (in Air).

The shape of the pressure versus time curve (at a fixed point in air in Mach Stem region) at various radii (exceeding 750 yd) obeyed the following equation: (Source: Ref. 300-13)

$$p(t) = P\left(1-\frac{t}{T_o}\right)e^{-t/T_o} \qquad \text{(Eq.1)}$$

Where P is the initial shock-wave pressure (psi) at the fixed point concerned, t is the time in seconds at which the pressure p(t) is desired, and T_o is the duration of the positive pressure pulse, evaluated in the preceding section. The shape is pictured in Ref. 300-13, Fig. 4.

For points less than 750 yd horizontal distance from the projected Zeropoint, the equation is of limited value, although it may still be applicable to the positive pressure pulse.

16.006 Velocity of the Shock Wave in Air.

No "best value" data were available in the office of the Technical Director on 1 Nov 46 as to the velocity of the shock wave in air.

Dr. R. M. Frye of Task Unit 1.5.2 presents (Ref. 510-1, Fig. II-B-1) the following preliminary (motion-picture film) data for the rate of propagation of the shock wave in air:

(1) Time after Mike Hour (sec)	(2) Horizontal distance from Projected Zero-point of intersection of shock-wave-in-air with the surface of the water (ft)	(3) Slant Range from Actual in-the-air Zeropoint to surface of water (ft)	(4) Slant-range-velocity, or rate of increase of the slant range as defined in Column (3) (ft/sec)
0.0	0	0	14,200
0.2	1020	1260	3,000
0.4	1600	1740	2,200
0.6	2000	2110	2,000
0.8	2380	2480	1,830
1.0	2700	2790	1,750
1.5	3530	3595	1,590
2.0	4350	4400	1,470

By 1 Nov 46 no estimate of probable error had been made. JTF-1 Technical Historian estimates the probable error to be in the neighborhood of 5 percent for data applicable to times more than 0.2 seconds after MIKE Hour.

An equation relating peak pressure P and shock-wave velocity U is given below. It is applicable in the region where the peak pressure in air was less than 500 psi, that is, at horizontal distances from the projected Zeropoint greater than 300 yd. (Source: Ref. 300-13)

$$P = \frac{7}{6} P_o \left[\left(\frac{U}{a}\right)^2 - 1 \right] \qquad \text{(Eq.2)}$$

Here P_o is the ambient atmospheric pressure (1012.2 millibars at sea level at MIKE Hour) and a is the ambient velocity of sound (1140 ft/sec at sea level at MIKE Hour). By 1 Nov 46 no estimate of probable error had been made.

16.007 Time of Arrival of Shock Wave in Air.

At distances greater than 5 mi the time of arrival of the shock wave in air was identical to that of an acoustical signal of low intensity, starting from a point 1665 ft nearer to the observer than is the actual detonation point. (Source: Ref 300-22)

The shock wave reached the surface of the water 56 milliseconds after MIKE Hour. (Source: Ref. 510-1)

16.008 Sound Produced.

The sound of the detonation was heard as a rather faint low rumble by persons 20 mi away on surface vessels.

16.009 Pressure within Target Vessels.

Peak pressures of 2.5 to 5 psi gage were reached in the (purposely-left-open) BRULE, situated 1005 yd from the projected Zeropoint. Peak pressure in closed ships never exceeded 2.5 psi gage. (Source: Ref. 300-13)

Chapter 17

Radiation and Radioactivity, Test A

Outline

Chapter 17

Radiation and Radioactivity, Test A

17.001 Introduction.

This Chapter discusses only radiations and radioactivity in Test A. Their effects are considered in other chapters.

17.002 Optical Radiation.

A. Total Emission. No meaningful value was obtained for the total quantity of energy emitted by the detonation as optical radiation. A value was obtained but it was absurdly high, being equal to twice the total amount of energy actually emitted by the detonation. (Source: Ref. 300-18; 300-7)

B. Spectral Distribution at Short Distance. No data were available by 1 Nov 46 as to the spectral distribution of the optical radiation at a specified short distance from the detonation point. At an unspecified (short) distance, and in a short range above 6000 A and in a short range below 4000 A (but not in the range from 4000 to 6000 A) the time-integrated intensity was inversely proportional to the fourth power of the wavelength. (Source: Ref. 300-18)

C. Flux at 18 Nautical Miles. At 18 nautical mi, on a surface vessel or on an airplane, the actually-received, time-integrated flux of optical radiation throughout the spectrum was 5×10^5 ergs/cm^2. (Source: Ref. 300-18) By 1 Nov 46 no estimate of probable error had been made.

D. Flux on Target Vessels. By 1 Nov 46 analysis of the data was not sufficiently advanced to give the time-integrated flux of optical radiation on target vessels.

E. Illumination at 12 Nautical Miles. At 12 nautical mi the peak illumination was approximately 100,000 ft-candles, which is roughly 10 times greater than is produced by noon summer sun and skylight. (Source: Ref. 510-1)

F. Spectral Distribution at Long Range. At 18 nautical mi, no optical radiation of wavelength less than 3200 A was received. The

wavelength of greatest intensity was 7000 A. The shorter the wavelength, the less was the intensity. This diminution in intensity was more pronounced than in the spectrum of the (noon) sun. Various atmospheric absorption lines appeared in the apectrograms. (Source: Ref. 300-18)

G. Time Distribution. There were no data for which the distribution of optical radiation can be computed as a function of time.

However, it is known that by the end of the first millisecond after Mike Hour only 7 percent of the total cumulative amount of 3600 A radiation to be received at 18 nautical mi had been received, and only 2 percent of the total cumulative amount of 9400 A radiation to be received had been received. (Source: Ref. 300-18)

Dr. R. M. Frye of Army Air Unit 1.5.2 reports that the total illumination at distant points passed through two maxima: principal maximum occurred at 0.1 milliseconds and the secondary maximum occurred at 120 milliseconds. (Source: Ref. 510-1)

17.003 Fireball.

The fireball was formed in the detonation itself. Its radius grew as follows:

Time after Mike Hour (sec)	Radius (ft)
10^{-5}	10
10^{-4}	40
10^{-3}	110
10^{-2}	260
10^{-1}	520
1	800
10	870

By 1 Nov 46 no estimate of probable error had been made.

The fireball ceased to exist as such at approximately 10 sec after Mike Hour. What had been the fireball became the mushroom top.

During the early growth the radius roughly obeyed this relationship:

$$R = 1678.\ T^{0.4} \qquad \text{(Eq. 1)}$$

Growth of the fireball to a radius of about 40 ft was by radiative transfer process; thereafter, growth was by mechanical or hydrodynamical process rather than by radiative process. (Source: Ref. 300-22)

The greatest surface temperature of the fireball was reached at 150 microseconds after Mike Hour, and the temperature value was in the neighborhood of 200,000° K. (Source: Ref. 300-22, Fig. 2) By 1 Nov 46 no estimate of the probable error had been made.

To observers 12 nautical mi away, the illumination produced per cm^2 of the fireball area was, at the instant of greatest brightness, several times that of the sun at noon; the color temperature of the fireball was considerably higher. (Source: Ref. 510-1)

17.004 Gamma Radiation.

A. Emission from the Detonating Bomb. No information is available as to total quantity of gamma radiation produced in the detonation. Much of the radiation was absorbed by the bomb materials themselves during the detonation process: much was absorbed by the air before reaching the Lagoon surface or target vessels; much was emitted after the great bulk of the fission products had been carried to higher altitudes.

The average energy emitted (per fission) as gamma radiation was 1.8 Mev. Approximately 40 percent of the energy represented by gamma radiation was (at the time the radiation was emitted) in the form of quanta of 5 Mev. (Source: Refs. 300-22, 300-20)

B. Time Incidence on Target Vessels. Forty five percent of the gamma radiation reaching the target vessels reached them by one sec after Mike Hour; 80 percent had reached them by 3 sec after Mike Hour; 99 percent had reached them by 10 sec after Mike Hour.

The great majority of the gamma radiation incident on target vessels came from the detonating bomb and from the fission products. It is estimated that less than 1 percent of the gamma radiation was from neutron capture in the non-fishant bomb materials. (Source: Ref. 300-22)

C. Total Quantity Reaching Specified Radius at the Surface of the Lagoon. The total cumulative amount of gamma radiation from the detonation proper (and from the fission products) reaching a specified point just above the surface of the water was as indicated below: (Source: Ref. 300-22, Fig. 5)

Horizontal Distance from Projected Zero-point. (yd)	Cumulative Gamma Radiation as defined above. (roentgens)
600	9000
700	6000
800	4000
900	2600
1000	1800
1100	1200
1200	770
1300	500
1400	330
1500	220
1600	150
1800	63
2000	28

The JTF-1 Technical Historian estimates that the probable error of these data is 15 percent.

These data conform to the following equation:

$$\text{No. of roentgens} = \frac{2.9 \times 10^{10} \times 10^{-R/845}}{R^2} \qquad \text{(Eq. 2)}$$

Where R is the (horizontal or slant) distance in yd. (Source: Ref. 303)

D. Atmospheric Attenuation Constant. At the instant of emission of the gamma radiation by the detonation proper the atmospheric attenuation constant was 340 meters (370 yd). That is, atmospheric absorption alone tended to reduce the radiation to 1/e (or 37 percent) of its initial value in traversing 340 meters of air at sea level. (Source: Refs. 300-20; also 300-22)

E. Induced Gamma Radiation. The total amount of induced gamma radiation in the Lagoon water, at 4 hr after Mike Hour was 0.5 roentgens per 24 hr in a central area of approximately 1 mi^2. This induced radiation resulted almost entirely from the formation of sodium 24 (half-life 14.8 hr) by neutron capture.

Induced gamma activity on target vessels which remained afloat was in general less than in the water. Materials rendered particularly radioactive were soap, salt, glass (which contained sodium) and arsenicals, brass, and a few other special items. (Source: Ref. 303)

17.005 Neutron Radiation.

The time-integrated flux of slow neutrons from the explosion varied with distance in approximate accordance with Eq.(3): (Source: Ref. 300-22)

$$\frac{\text{No. of slow neutrons}}{\text{cm}^2} = 2.24 \times 10^{12} \times 10^{-(R/550)^2}, \qquad \text{(Eq. 3)}$$

where R is the slant range in meters.

The time-integrated flux of fast neutrons from the explosion varied with distance as indicated by the following table: (Source: Ref. 300-20)

Slant Range (yd)	Time-Integrated Flux of fast neutron per unit area at the indicated slant range (neutrons per cm^2)
400	1×10^{11}
600	1.6×10^{10}
800	3.3×10^{9}
1000	8×10^{8}

The atmospheric attenuation constant of fast neutrons was (at slant range greater than 800 yd) 160 yd. That is, scattering by the atmosphere over a path length of 160 yd reduced the flux of fast neutrons to 1/e (or 37 percent) of its initial value. At shorter ranges, the attenuation with distance was less. (Source: Ref. 300-22)

Neutrons reaching the water produced radioactive sodium 24, which has a half-life of 14.8 hr. Neutrons were absorbed also by hydrogen and chlorine in the water, by sodium, zinc, and arsenic in target vessels, and of cource, by nitrogen in the air. (Source: Ref. 300-20)

17.006 Alpha Radiation.

Very little alpha radiation was present at the surface of the Lagoon: its effect was negligible.

17.007 Beta Radiation.

Although considerable beta radiation was produced in the immediate neighborhood of the detonation, very little such radiation was present at the surface of the Lagoon. Its effect was negligible.

17.008 Gamma and Neutron-Radiation Dosages in Target Vessels.

Gamma-radiation dosages on the most exposed topside parts of target vessels were, of course, substantially as indicated in Sec. 17.004.

Gamma-radiation dosages on topside regions shielded by superstructures and in interior compartments were usually far less, typically by a factor of 10 to 100. (Source: Ref. 300-20)

(Dosages on submerged submarines would presumably have been negligible. However, no submarines were submerged during Test A.)

Neutron-radiation dosages on the most exposed topside parts of target vessels were, of course, substantially as indicated in Sec. 17.005. Dosages in "shielded" regions of the vessels were not greatly reduced, since neutrons are not greatly absorbed by steel or other materials common in vessels.

17.009 Residual Radioactivity on Target Vessels.

The residual radioactivity, i.e., radioactivity present after one minute after Mike Hour, on target vessels was low. Residual radioactivity on A-Day itself was not determined. One day after A-Day radioactivities greater than 0.1 roentgens per 24 hr were found on only 13 vessels. (Source: Ref. 300-20)

One day after A-Day the three most radioactive (not-immediately-sunk) vessels were SKATE, ARKANSAS, and SAKAWA. (Source: Ref. 300-20) The maximum radioactivity measured on any surviving ship was at that time approximately 8 roentgens per 24 hr. This value was found for a pool of water on the ARKANSAS. (Source: Ref. 303)

17.010 Residual Radioactivity in the Water.

The residual radioactivity in the water after Mike Hour was negligible and of no physiological significance. Thus at 4 hr after Mike Hour in an 0.8 mi^2 area roughly centered at the projected Zero-point, the intensity was only 0.5 roentgens per 24 hr. By 30 hr after Mike Hour the figure had decreased to 0.1 roentgens per 24 hr. (Source: Ref. 300-20)

Principal cause of the radioactivity in water was neutron-produced radioactive sodium 24, of 14.8-hr half-life. (Source: Ref. 300-20) This sodium isotope emits beta particles and gamma rays.

17.011 Residual Radioactivity in Air.

There was appreciable residual radioactivity in the air about 70 mi to leeward 13 to 17 hr after Mike Hour, and detectable radioactivity in the air roughly 4000 mi away (Puget Sound Area) 150 hr after Mike Hour. (Source: Ref. 300-20 and Ref. 300-19)

This radioactivity originated, of course, in the fission products dispersed in the air.

Chapter 18

Other Detailed Results of Test A

Outline

Chapter 18

Other Detailed Results of Test A

18.001 The Cloud.

By 20 sec after Mike Hour the cloud had assumed its characteristic mushroom shape and was one mile high. By 150 sec after Mike Hour it had reached an altitude of nearly 5 mi; its maximum width was 9000 ft, and a thin cap, presumed by some to be an ice cap, had formed. By 400 sec after Mike Hour the cloud had reached an altitude of 7 mi. (Source: Ref. 510-1)

Practically all the fission products produced in the detonation rose in the cloud; they were detected several days later at great distance, as explained in a following section.

18.002 Water Waves.

Water waves produced in the Test were of negligible significance. At the projected Zeropoint the surface of the water was first depressed by approximately 6 ft; the depression lasted for approximately 8 sec. The depression was followed by a rapid rise to a height of 2 ft above the normal level, after which the surface returned to normal level. (Source: Ref. 300-16)

18.003 Other Results.

A. Radioactivity at Great Distance. Radioactivity from the explosion was definitely detected at many remote sites. At the Puget Sound Naval Shipyard, for example, the counting rate near the surface of the earth increased by 35 percent approximately 150 hr after Mike Hour. (Source: Ref. 300-19)

B. Reflectivity and Conductivity Phenomena. No atmospheric reflectivity or conductivity phenomena were detected at great distances. Even locally no noteworthy effects were found.

C. Seismological Phenomena. No earth shock was detected at appreciable distance.

D. Magnetic Phenomena. No magnetic phenomena were detected.

E. Ionization Phenomena. No significant ionization phenomena were detected.

F. Remote Detection. Remote detection was accomplished only by radioactivity in the air. See the foregoing Paragraph A.

Chapter 19

Correlation and Discussion of Test A

Outline

Section

Chapter 19

Correlation and Discussion of Test A

19.001 Introduction.

This Chapter contains, first, general correlations and conclusions regarding the outcome of Test A, and second, various comments on the adequacy and success of the Test from a technical and technical-administrative point of view.

The correlations and conclusions are for the most part those of the JTF-1 Technical Historian. Most of them have not been approved, and it is expected that further study by experts will lead to minor changes in the correlations and conclusions. The tentative findings presented here are intended (1) to give a rough over-all picture of the outcome of the Test, and (2) to serve as a basis of discussion.

19.002 Loss of Military Efficiency of Ships.

A. Introduction. A rough but simple definition of military efficiency of a ship itself is included in Appendix III.

B. Immediate Loss. Fig. 19.1 shows the range (estimated by the JTF-1 Technical Historian) at which specified extent of immediate (i.e., first hour) loss of military efficiency of "typical" surface combatant vessels themselves is probable (probability equal to 50 percent). Ranges are horizontal distances from the projected Zeropoint. Estimates apply to U. S. surface combatant vessel of unspecified type.

The pertinent data are:

Range for very serious immediate loss:	900 yd
Range for serious immediate loss:	1000 yd
Range for moderate immediate loss:	1300 yd
Range for slight immediate loss:	1500 yd

C. Long Term Loss. It is not possible to make useful estimates as to the long term loss of military efficiency of ships themselves. Even serious loss of military efficiency of a ship itself may be corrected in hours or days in some cases, especially if the ship is very close to a repair yard; yet even small loss of military efficiency of the ship itself may take months to correct, if the damage is deep-seated and if the ship is far from base.

D. Weakest Link. At ranges greater than 700 yd the weakest links as regards loss of military efficiency of ships themselves are: stacks and boilers (most important), and antennas. Within 700 yd hulls and ordnance equipment become weak links also.

19.003 Loss of Military Efficiency of Crews.

A. Introduction. A rough but simple definition of efficiency of a crew per se is included in Appendix III.

B. Immediate Loss. Fig. 19.1 shows the range (estimated by the JTF-1 Technical Historian) at which specified extent of immediate (i.e., first hour) loss of military efficiency of crews per se would be probable (probability equal to 50 percent). (Normal 1945 shielding is assumed; also "typical" type and orientation of ship.) The ranges of principal interest are:

Range for very serious immediate loss of efficiency	700 yd
Range for serious immediate loss of efficiency	800 yd
Range for moderate immediate loss of efficiency	900 yd
Range for slight immediate loss of efficiency	1000 yd

C. Long Term Loss. Principal ranges for long term loss (of indicated severity) of military efficiency of crews per se are:

Range for very serious long term loss	800 yd
Range for serious long term loss	1100 yd
Range for moderate long term loss	1400 yd
Range for slight long term loss	1700 yd

However, the significance of these figures is questionable since it would often be possible to replace the crew within a few weeks.

D. Weakest Link. It appears that, at virtually all horizontal ranges of interest, the type of injury producing greatest immediate loss of military efficiency to crews would be injury from air blast, including primary effects, secondary effects (injury from impact with flying debris, ship structures, etc.) and general confusion created. Next in importance would be burns, injury to lungs and eardrums, and injury to bone marrow and white blood corpuscles.

19.004 Loss of Combined Military Efficiency.

A. Introduction. For simplicity, the abbreviation CME is used below for "combined military efficiency." A rough but simple definition of combined military efficiency is included in Appendix III. The term refers, of course, to the efficiency of ship and ship's crew con-

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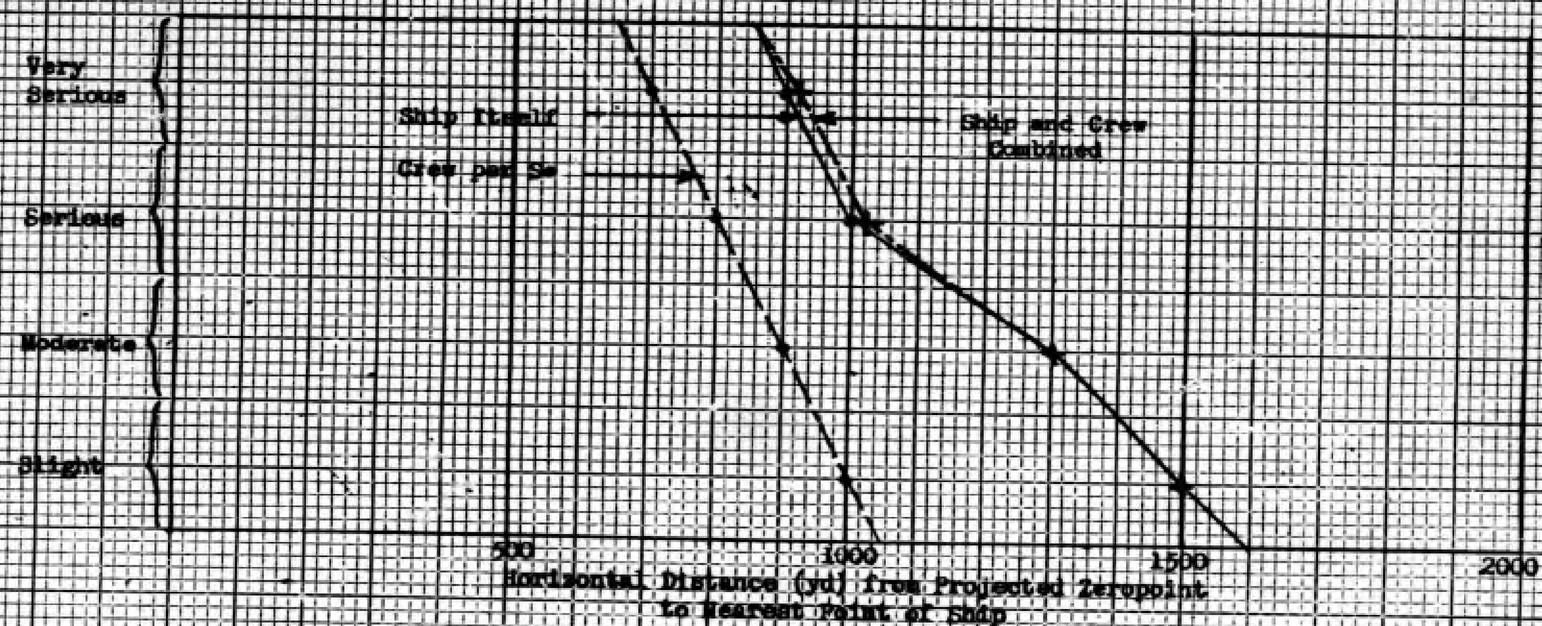

Fig. 19.1 Immediate Loss of Military Efficiency Versus Range, Test A

Source: Estimates by JTF-1 Technical Historian

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sidered in combination.

B. Immediate Loss. Figure 19.1 shows the range (estimated by the JTF-1 Technical Historian) at which specified extent of immediate (i.e., first hour) loss of combined military efficiency would be probable (probability equal to 50 percent).

The most interesting ranges are:

Range for very serious immediate loss of CME	900 yd
Range for serious immediate loss of CME	1020 yd
Range for moderate immediate loss of CME	1300 yd
Range for slight immediate loss of CME	1500 yd

C. Long Term Loss. For reasons indicated in the preceding sections, it is impossible to make any meaningful estimate of long term losses of combined military efficiency.

D. Weakest Link. The weakest link, as regards immediate loss of combined military efficiency, is the ship itself, especially stacks, boilers, antennas and (within 700 yd) hulls and ordnance equipment.

19.005 Decreasing the Ranges of Loss of Military Efficiency of the Ships Themselves.

Considerable reduction in the ranges at which the ships themselves suffer specified losses of military efficiency could be achieved by improving the resistance of stacks and masts (masts supporting antennas).

Such improvements might reduce the ranges of serious and very serious immediate loss of military efficiency by approximately 100 yd.

19.006 Decreasing the Ranges of Loss of Military Efficiency of the Crews Per Se.

Considerable reduction in the ranges at which the crews would suffer specified immediate losses of military efficiency could be achieved by placing all personnel inside ships or by providing topside personnel with protection against the pressure wave in air. (Care would have to be taken to see that the screens themselves could not become missiles.)

Providing steel screens to reduce the intensity of gamma radiation would not be of appreciable value as far as efficiency during the first hour is concerned, except perhaps at short range; and even here the value would be small because the ships would ordinarily be out of the battle.

19.007 Decreasing the Ranges of Loss of Combined Military Efficiency.

Since, during the first hour after an air burst, damage to ships is the all-important consideration as far as immediate military efficiency is concerned, reducing the ranges of ship vulnerability is the obvious immediate goal. (See Sec. 19.005.)

19.008 Ranges of Damage or Injury Produced by Causative Factors.

A. Introduction. No formal analysis has been made as to what causative factors are predominant at various specified ranges; however, the following estimates by the JTF-1 Technical Historian may be of value:

B. Shock Wave in Air. Shock wave in air is the cause of greatest immediate loss of military efficiency of ships.

A typical surface vessel will probably be sunk by a pressure wave in air having a peak pressure greater than 35 psi gage; it will probably suffer very serious immediate loss of military efficiency when subjected to a peak pressure greater than 25 psi gage; peak pressures of 20, 15, and 10 psi gage will probably produce serious, moderate, and slight immediate losses of military efficiency, respectively.

Shock wave in air (including primary and secondary effects) is comparable to optical radiation as a cause of immediate loss of military efficiency of crews at ranges greater than 900 yd. Peak pressure of 10 to 100 psi gage might be required to produce death as a primary effect; peak pressures as low as 5 psi gage might cause death from secondary effects of impact with ship structures.

C. Gamma Radiation. Gamma radiation would contribute very little to the immediate loss of combined military efficiency. It would be of slight importance at ranges less than 1000 yd, and of negligible importance at greater ranges.

Gamma radiation would probably be the greatest cause of long-term loss of military efficiency of crews on ships within 1500 yd, since (unlike the shock wave in air) it would produce serious injury even to persons protected by thin and moderately thin layers of steel; that is, it would affect personnel below decks in addition to affecting topside personnel. Exposed persons at range of 1350 to 2000 yd might die from exposure to gamma radiation, but the probability would be less than 50

percent. Exposed persons within 1350 yd would probably die from exposure to gamma radiation. Best protected persons as close as 600 yd might not receive lethal gamma radiation doses.

A gamma radiation dose of 400 roentgens would probably be fatal to man. After exposure to such a dose, nausea sets in within 30 to 60 min; weakness develops gradually after the first day, and mortality probably would result within one month.

A gamma radiation dose of over 2000 roentgens would produce nausea within approximately 30 minutes and weakness might often develop within 60 min; death would occur within 36 hr.

Gamma radiation intensity is reduced to 50 percent by a 2-cm thickness of steel, and to approximately 1 percent by 14 cm (5½ in.) of steel. Thus 2 cm. of steel would reduce the lethal radius from 1350 yd to 1200 yd, and 14 cm of steel would reduce the lethal radius to less than 600 yd. (However, neutron radiation would become very serious at ranges of less than 650 yd, and would not be adequately stopped by 14 cm of steel, as explained below.)

D. Neutron Radiation. Neutron radiation would contribute virtually nothing to the immediate loss of combined military efficiency.

Neutron radiation would contribute virtually nothing to the long-term loss of military efficiency of crews outside 700 yd.

Neutron radiation would be the greatest cause of injury to personnel in "very well protected" regions on ships within the annulus extending from 550 to 650 yd. In this annulus even 15 cm of steel would afford little protection.

Since it is probable that a surface combatant ship of unspecified type situated within 550 yd sinks, it is probable that neutron radiation is of reduced military importance within that range.

The neutrons which are present in the 550 to 650-yd annulus are slow neutrons; fast neutrons are almost non-existent beyond 550 yd.

E. Other Causative Factors. Optical radiation (heat flash) would rival shock wave in air as principal cause of immediate loss of military efficiency of crews at ranges greater than 900 yd. It would produce serious (second degree) burns on exposed skin at ranges as great as roughly 1700 yd.

Beta radioactivity, alpha radioactivity, and induced radioactivity were not important.

Unfished fissionable materials were not present (i.e., at sea level) in significant quantities.

Importance of psychological effects (as on persons who might know they would soon die from effects of gamma radiation) was not investigated.

F. Comparison of the Effectiveness of the Various Causative Factors.

Air blast (including primary and secondary effects, and the general confusion created) would be the most important cause of immediate loss of combined military efficiency. This is true for all ranges.

The same statement applies to immediate loss of military efficiency of ships.

Within 650 yd, principal cause of immediate loss of military efficiency of crews would be neutron radiation; in the annulus from 650 to 900 yd the principal cause would be gamma radiation; outside 900 yd shock wave in air and optical radiation would be collectively the principal cause.

19.009 Technical Shortcomings of the Test.

Although the Test was in the main almost completely successful, several shortcomings deserve mention.

A. The Bomb Miss. The plan-view position of the bomb at the instant of detonation was 710 yd from the intended projected Zeropoint -- foremast of NEVADA -- and at 281° True. The projected actual Zeropoint was 700 yd west and 136 yd north of the intended projected Zeropoint. (Note that the slant range was not between 1500 and 2000 ft, as originally announced, but was 2130 ft.)

The cause of the miss had not been determined by 15 Nov 46, and it is likely that the cause will never be discovered. Extensive studies have been made by several groups, but neither separately nor collectively do the findings explain the miss. There is strong evidence that the bombing plane was at approximately the correct altitude, that the bombsight was in proper condition and adjustment, that the ballistic wind correction was appropriate, and that the bomb was released at the correct instant and started its descent in normal manner. (The time of fall was 48.1 ± 0.3 sec, which was 0.5 sec longer than predicted; such a deviation is suggestive of a slightly rough flight but is inconsistent with a bad wobble or a spiral flight.) There is also weighty evidence that the bomb itself was of very sound and strong aerodynamic design and should not have wobbled or drifted. Data available on 1 Nov 46 ascribe to the bombing plane a position and course (at the instant of bomb release) such as to place the bomb 600 ft to the left of the intended Zeropoint and at least 1000 ft over, which by no means corresponds with the actual detonation point. Since there is at present no tenable hypothesis as to why the miss occurred, the matter will not be discussed here.

It is well known that the miss prevented the optimum functioning of many of the instruments, prevented conclusive demonstration as to whether an air burst can sink a battleship, and had other deleterious consequences.

B. Timing-Signal Failure. Two individual errors produced the timing-signal failure, as a result of which a considerable number of instruments were started late and thus failed to obtain the desired data. First, the timing control operator made a premature decision that the expected tone break (in the signal transmitted from the bombing plane) had occurred; he then (prematurely) started the automatic timers controlling the timing signals; and when he found that the tone break had not occurred, he had to abandon the automatic timers. Second, after switching to manual keying, the timing control operator read the time from the wrong clock — one which was based on the minus-2-min mark as given by the bombardier and not expected to be highly accurate.

C. Black-Box Failures. A small but appreciable fraction of the "black-box" instrument-starting devices failed to operate successfully, with the result that the corresponding instruments failed to obtain the desired data. In some instances the black-box failures were merely the result of lack of time to carry out adequate tests; in some instances the boxes were affected by the high (radio) noise level in the target array area, the noise level being especially high just at How Hour. In some instances the black-box failures were partly a result of administrative division of responsibility, one group being responsible for the boxes themselves and a different group being responsible for the apparatus into which the black-box signal was fed.

D. Excessive Density of Goggles. The goggles distributed among important technical and observer personnel were unnecessarily dense.

19.010 General Appraisal of the Test.

From the technical point of view as well as from the operational point of view the Test was very successful. Graded damage was produced in ships of many types; graded injury was produced in animals of several types; and the principal physical phenomena (causative factors) were evaluated with reasonably good accuracy. A firm basis was established for determining the vulnerability of ships and crews to air bursts of atomic bombs, and for improving future designs and tactics.

Shortcomings there were. But they were few in number, noncrucial in character, and, in view of the shortage of time and technical personnel and the unique character of the problems presented, it is difficult to see how they could have been avoided.

Chapter 20

Execution of Test B

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List of Tables

Chapter 20

Execution of Test B

20.001 Introduction.

Whereas Bomb A was detonated in the air while falling freely, Bomb B was detonated while at rest beneath the surface of the water.

20.002 Delivery of Bomb.

The Bomb was delivered to LSM-60 by means outside the scope of this report. See Chap. 5 for a description of the final positioning beneath LSM-60.

20.003 Detonation of Bomb.

The bomb was detonated (by means described in Chap. 5) at 59.7 sec after 0834 on 25 July 46, Bikini Local Time. This corresponded to 1634:59.7 on 24 July (EST) and 2134:59.7 on 24 July (GCT). Final firing signals were sent out from the CUMBERLAND SOUND.

At the instant of detonation, the location of the bomb was as follows:

Depth below Lagoon surface: 90 ft.

Latitude: 11° 35' 05" N.

Longitude: 165° 30' 30" E.

20.004 Status of Actual Array of Target Vessels.

Table 20.1 shows the B-Day, Mike Hour positions and aspects of the target vessels.

Table 20.2 shows the conditions of target vessels within 1000 yd of Zeropoint as regards fuel and ammunition loads.

TABLE 20.1. RELATIVE POSITIONS OF TARGET VESSELS ON B-DAY AT MIKE HOUR.
Note: All distances are horizontal distances from actual projected Zeropoint.

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Vessel	Range fm Burst to Bow (Yd)	True Bearing of Bow from Burst		Relative Bearing of Burst from Bow		Coordinates of Vessel from Burst (Yd)				Distance from Burst to Nearest Part of Vessel (Yd)	Direction of Burst from Vessel
						Bow		Stern			
		deg	min	deg	min	X	Y	X	Y		
Battleships & Cruisers											
Arkansas, BB 33, 562*	259	10	26	107	16	47 E	255 N	138 W	232 N	223	Stbd. Beam
New York, BB 34, 573	1007	109	54	183	10	943 E	341 S	763 E	288 S	820	Stern
Nevada, BB 36, 583	1056	8	53	94	16	163 E	1042 N	29 W	1057 N	1030	Stbd. Beam
Pennsylvania, BB 38, 608	1283	174	46	156	19	117 E	1278 S	182 E	1085 S	1104	Stbd. Qtr.
Pensacola, CA 24, 586	640	270	27	356	41	641 W	5 N	836 W	15 N	640	Bow
Salt Lake City, CA 25, 586	1256	61	57	134	37	1108 E	590 N	923 E	650 N	1120	Stbd. Qtr.
Nagato, JAP BB,	852	29	52	122	0	424 E	739 N	178 E	730 N	745	Stbd. Qtr.
Sakawa, JAP CL,	Sunk during Test A										
Prinz Eugen, IX 300,	1990	298	48	309	08	1744 W	959 N	1767 W	1169 N	1990	Port Bow
Aircraft Carriers											
Saratoga, CV 3, 910	446	208	03	124	10	210 W	395 S	93 E	360 S	350	Stbd. Beam
Independence, CVL 22, 619	1436	245	54	259	24	1311 W	587 S	1361 W	383 S	1390	Port Beam
Destroyers											
Lamson, DD 367, 344	Sunk during Test A										
Conyngham, DD 371, 344	3597	295	03	308	51	3259 W	1523 N	3286 W	1640 N	3597	Port Bow
Mugford, DD 389, 341	2595	309	04	314	30	2015 W	1636 N	2028 W	1752 N	2595	Port Bow
Talbot, DD 390, 341	1835	249	23	263	12	1719 W	647 S	1746 W	533 S	1815	Port Beam
Mayrant, DD 402, 341	813	338	33	352	18	297 W	757 N	324 W	870 N	813	Bow
Trippe, DD 403, 341	1320	333	37	345	16	587 W	1183 N	608 W	1300 N	1320	Bow
Rhind, DD 404, 341	2240	313	41	317	09	1619 W	1546 N	1625 W	1663 N	2240	Port Bow
Stack, DD 406, 341	2003	317	41	322	28	1350 W	1483 N	1360 W	1595 N	2003	Port Bow
Wilson, DD 408, 341	1766	322	29	329	29	1075 W	1400 N	1092 W	1517 N	1766	Port Bow
Hughes, DD 410, 348	643	81	58	97	10	637 E	90 N	607 E	202 N	635	Stbd. Beam
Anderson, DD 411, 348	Sunk during Test A										
Mustin, DD 413, 348	1280	78	45	86	18	1257 E	250 N	1239 E	365 N	1280	Stbd. Beam
Wainwright, DD 419, 348	2952	302	56	314	25	2478 W	1605 N	2501 W	1719 N	2952	Port Bow
Submarines											
Skipjack, SS 184, 299	808	179	30	273	30	7 E	808 S	90 W	813 S	800	Port Beam
Searaven, SS 196, 310	1419	194	49	318	49	362 W	1370 S	446 W	1427 S	1419	Port Bow
Tuna, SS 203, 299	1800	213	03	340	24	981 W	1509 S	1061 W	1574 S	1800	Bow
Skate, SS 305, 311' 6"	886	228	30	324	28	670 W	584 S	775 W	594 S	886	Port Bow
Apogon, SS 308, 311' 6"	846	207	31	303	10	392 W	751 S	487 W	761 S	846	Port Bow
Dentuda, SS 335, 311' 6"	1466	220	16	31	52	947 W	1118 S	962 W	1215 S	1466	Stbd. Bow
Parche, SS 384, 311' 6"	1670	229	00	210	58	1260 W	1095 S	1229 W	994 S	1580	Port Qtr.
Pilotfish, SS 386, 311' 6"	363	68	07	186	25	336 E	135 N	246 E	88 N	260	Stern
Landing Craft											
LST 52, 328	1546	8	09	27	27	220 E	1531 N	195 E	1638 N	1546	Stbd. Bow
LST 133, 328	723	61	58	152	16	639 E	340 N	525 E	339 N	630	Stbd. Qtr.

* Length of Ship in Feet.

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TABLE ?0.1. RELATIVE POSITIONS OF TARGET VESSELS ON B-DAY AT MIKE HOUR. (Con't)
Note: All distances are horizontal distances from actual projected Zeropoint.

Vessel		Range fm Burst to Bow (Yd)	True Bearing of Bow from Burst		Relative Bearing of Burst from Bow		Coordinates of Vessel from Burst (Yd)				Distance from Burst to Nearest Part of Vessel (Yd)	Direction of Burst from Vessel
							Bow		Stern			
			deg	min	deg	min	X	Y	X	Y		
Landing Craft (con't.)												
LST 220,	328*	3466	00	10	13	10	Incomplete Information					
LST 545,	328	4143	358	15	341	45	Incomplete Information					
LST 661,	328	2653	02	00	3			"	"			
LCI 329,	159	3266	74					"	"			
LCI 327,	159	2433	79					"	"			
LCI 332,	159	1873	86	35	275	15	1871 E	112 N	1881 E	59 N	1870	Port Beam
LCI 549,	.159	3933	74				Incomplete Information					
LCT 705,							4160 W	473 S	Incomplete Information			
LCT 745,	120						Incomplete Information					
LCT 816,	120	798	56	40	72	37	667 E	438 N	660 E	478 N	798	Stbd. Bow
LCT 818,	120	1396	34	00	241	32	782 E	1159 N	797 E	1121 N	1370	Port Qtr.
LCT 874,	120	2426	48				Incomplete Information					
LCT 1013,	120						4070 W	684 N	Incomplete Information			
LCT 1078,	120	2933	47				Incomplete Information					
LCT 1112,	120	3500	47					"	"			
LCT 1113,	120	4300	49					"	"			
LCT 1114,	120	483	20	13	28	03	167 E	453 N	160 E	493 N	483	Stbd. Bow
LCT 1115,							3407 W	2336 S	Incomplete Information			
Merchant Craft												
Gilliam, APA 57,	426	Sunk during Test A										
Banner, APA 60,	426	2499	264	07	281	15	2487 W	256 S	2527 W	118 S	2490	Port Beam
Barrow, APA 61,	426	2054	268	08	279	48	2053 W	66 S	2059 W	74 N	2049	Port Beam
Bladen, APA 63,	426	2623	169	01	185	27	498 E	2567 S	458 E	2427 S	2480	Stern
Bracken, APA 64,	426	1560	156	55	164	30	612 E	1436 S	592 E	1294 S	1420	Stern
Briscoe, APA 65,	426	950	133	03	237	08	695 E	649 S	556 E	684 S	878	Port Qtr.
Brule, APA 66,	426	867	295	51	310	46	781 W	378 N	817 W	517 N	867	Port Bow
Butte, APA 68,	426	2785	258	58	276	06	2737 W	534 S	2777 W	397 S	2780	Port Beam
Carlisle, APA 69,	426	Sunk during Test A										
Carteret, APA 70,	426	3229	254	52	277	13	3117 W	843 S	3175 W	710 S	3218	Port Beam
Catron, APA 71,	426	1326	146	18	149	52	737 E	1104 S	727 E	963 S	1210	Stbd. Qtr.
Cortland, APA 75,	426	3875	248	30	276	45	3622 W	1392 S	3683 W	1266 S	3870	Port Beam
Crittenden, APA 77,	426	1686	273	33	282	55	1684 W	105 N	1707 W	248 N	1686	Port Beam
Dawson, APA 79,	426	1190	283	59	299	09	1155 W	288 N	1194 W	428 N	1190	Port Bow
Fallon, APA 81,	426	466	302	59	330	38	391 W	254 N	456 W	379 N	466	Port Bow
Fillmore, APA 83,	426	2150	163	04	172	02	627 E	2058 S	603 E	1916 S	2012	Stern
Gasconade, APA 85,	426	716	152	51	165	33	326 E	637 S	263 E	498 S	580	Stern
Geneva, APA 86,	426	2920	171	10	196	56	446 E	2880 S	386 E	2743 S	2780	Port Qtr.
Niagara, APA 87,	426	3186	174	11	201	35	323 E	3170 S	260 E	3042 S	3060	Port Qtr.
Concrete Drydocks & Barges												
YO-160,		543	105	30	190	30	524 E	145 S	399 E	132 S	425	Stern
YOG 83,		1090	321	10	21	45	684 W	849 N	795 W	912 N	1090	Stbd. Bow
ARDC 13,		1276	27	25	114	45	587 E	1132 N	457 E	805 N	1217	Stbd. Qtr.

* Length of Ship in Feet.

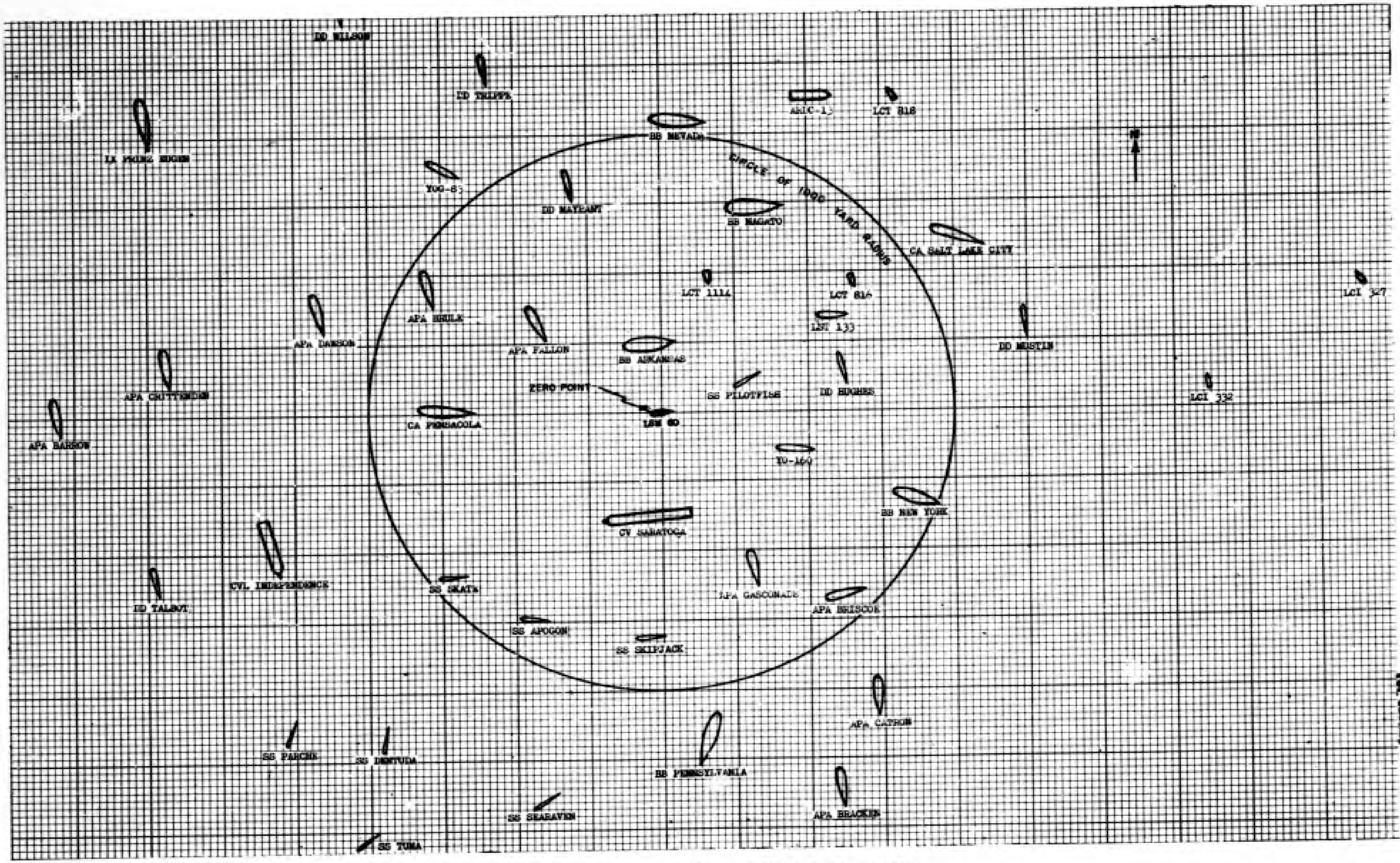

FIGURE 20.1. TEST B TARGET ARRAY [INNER PORTION] SHOWING POSITIONS OF TARGET VESSELS RELATIVE TO PROJECTED ZEROPOINT ON B-DAY AT MIKE HOUR.

TOP SECRET

TABLE 20.2

Test B Fuel and Ammunition Loads on Target Vessels Within 1000 Yd

Note: Percentages refer to percentage of normal load, abbreviated N. Normal load ordinarily means approximately 95 percent of capacity. M indicates minimum load, ordinarily approximately 10 percent of capacity.

Target Vessel	Fuel Load (percent)	Ammunition Load (percent)
Battleships & Cruisers		
Arkansas	50	50
Nagato	15	M
New York	M	M
Pensacola	15	67
Aircraft Carriers		
Saratoga	M	67
Destroyers		
Hughes	15	67
Mayrant	50	50
Submarines		
Apogon	50	50
Pilotfish	N	N
Skate	33	67
Skipjack	50	50
Landing Craft		
LST 133	M	M
LSM 60	-	-
LCT 816	*	*
LCT 1114	*	*
Merchant Craft		
Briscoe	M	M
Brule	M	M
Fallon	N	N
Gasconade	N	N
Concrete Drydocks & Barges		
YO 160	*	*

* No ammunition aboard; no information available in DSM office as to the actual amount of fuel aboard.

20.005 Status of Actual Array of Other Targets.

A. Airborne Targets. Four Army and three Navy drones were airborne on B-Day at Mike Hour. They were located as follows:

Drone.	Altitude (ft)	Approx. Slant Distance from Zeropoint (nautical mi)	Bearing from Zeropoint (Degrees True)
B-17 Fox	6000	1	267
B-17 George	16000	3	267
B-17 How	7000	13	090
B-17 Love	11000	19	090
F6F Red Dog	14000	20	315
F6F White Dog	9000	20	315
F6F Blue Dog	5000	20	315

B. Shore Targets. Eighteen landing craft were exposed on the beach at Bikini, between 5500 and 6000 yd from Zeropoint. These included:

TYPE	QUANTITY	IDENTIFYING NUMBER
LST	1	125
LCI	2	615, 620
LCT	4	412, 812, 1187, 1237
LCM	5	1, 2, 3, 4, 6
LCVP	6	7, 8, 9, 10, 11, 12

C. Other Targets. Two PBY3 seaplanes were on the surface between 2500 and 3500 yd from Zeropoint; bearing approximately 272° true.

20.006 Status of Air and Water.

A. Air. The Equatorial Front was north of Bikini on B-Day, Mike Hour. There was a light (7 knots) southeasterly wind at the surface, shifting with altitude through east to moderately strong northeasterlies above 35,000 ft. At low altitudes the cloud cover was approximately two-tenths (cumulus); there were no clouds at intermediate altitudes, and the cover above 30,000 ft was approximately one tenth (cirrus). Surface air temperature was 86°F., and relative humidity was 73 percent.

B. Water. Within the Lagoon a state ONE sea condition existed (waves less than 1 ft high), water temperature was 82°F., and salinity was 34.75 g per kg. There was a wind-driven surface current running west northwesterly at a speed of 0.15 knot, and a subsurface (below 40 ft) current running easterly at less than 0.1 knot.

20.007 Status of Personnel.

Practically the entire complement of personnel in the Bikini area observed the explosion. Nearly all persons were aboard the non-target vessels, some were aboard planes. No persons were aboard target vessels.

Nearest non-target vessels, (at 8 to 10 mi from Zeropoint) were:

MT. MCKINLEY, CUMBERLAND SOUND, ALBEMARLE, HAVEN, WHARTON, KENNETH WHITING, AVERY ISLAND, BLUERIDGE, BEGOR, HENRICO, WALKE, LAFFEY, O'BRIEN, BARTON, PANAMINT.

The nearest manned plane at Mike Hour was an F-13 (modified B-29) photographic plane, at an altitude of 30,000 ft and a slant range of approximately 6 nautical mi from Zeropoint.

20.008 Re-entry.

Re-entry into Enyu Channel was accomplished rapidly and without incident. The radiological reconnaissance PGM's were the first manned craft to re-enter the Lagoon. Following them (at 1015) came the ships of Task Unit 1.2.8, carrying the radiological safety patrol small craft. At 1230 FALL RIVER took station in Enyu Channel and vessels of Task Unit 1.2.7 (Salvage Unit) entered the Lagoon. MT. MCKINLEY entered the channel at 1700.

Within two hours after Mike Hour, drone boats had penetrated the target array area, and before dark, four individual forays had been made by drone boats. Water samples were collected, brought to ALBEMARLE, and taken by her to Kwajalein to be analyzed for radioactivity. Drone boat activities continued through 29 July.

The technical non-target vessels re-entered the Lagoon on the afternoon of B-Day (25 July) and anchored in the lower anchorage near the Lagoon entrance. On 27 July, they moved to their permanent berths near the target array; but on 28 July they were forced back down to the lower anchorage by an upswelling of radioactivity in the vicinity of the target array. On 30 and 31 July all vessels, including the non-technical vessels which had remained under way in the evacuation operating areas outside the Lagoon since B-Day, returned to their permanent berths. Vessels in the northern part of the anchorage accumulated considerable radioactivity in their evaporators, and on 2 Aug were shifted to uncontaminated berths near the Lagoon entrance, where they remained until 7 Aug.

The "Red Line" and "Blue Line," demarking respectively areas of severe (1 roentgen per day) and moderate (0.1 roentgen per day)

exposure were determined and plotted on charts; new charts were made every few hours, at first, and then at less frequent intervals. These lines sometimes advanced, sometimes receded; and as the lines moved, the radiological safety teams, damage control teams, salvage teams, and key observers took advantage of whatever opportunities arose to inspect and service the target vessels.

By nightfall on B-Day initial boarding teams had boarded twelve of the outer target vessels; five days later, 35 vessels had been thus boarded; and by 5 Aug 46, each vessel had been thus boarded at least briefly.

Drone planes had, of course, "re-entered" the target-array area immediately after the detonation. In fact, one such plane was within a mile of Zeropoint at Mike Hour and received very strong shock. All drone planes collected air samples, Navy drones returning with their samples to Roi and Army drones returning to Eniwetok. Samples were transferred to Kwajalein for analysis.

First manned planes to fly into the immediate vicinity of the target array after the detonation were two PBM's, "CHARLIE" and "DOG," which moved in from their 5-mi-distant orbiting positions to observe damage and measure radioactivity. PBM "CHARLIE" made its first report on sinkings about 30 min after Mike Hour, and thereafter many flights across the array were made, principally for photographing the demise of SARATOGA. (The sinking of NAGATO occurred at night and was not observed or photographed.)

The inspection of vessels and instruments and the removal of animals were carried out rapidly after the vessels were reboarded. Recovery of animals was completed five days after B-Day.

The day after B-Day, HUGHES, which was low in the water, was beached by Task Unit 1.2.7; two days after B-Day, FALLON, which was low in the water and listing, was beached.

Decontamination processes were started promptly. For some of the most highly contaminated vessels decontamination measures were continued intermittently for several months. In some cases decontamination activities are expected to continue into 1947.

Instruments and animals were examined immediately after recovery; photographic film was processed and analyzed; and voluminous technical reports were rapidly prepared.

20.009 Sinkings.

Salient data on sinkings and times of sinkings are recorded below: (See a later chapter for details.)

LSM-60 was disintegrated at Mike Hour. Fragments were noticed to splash in several sectors of the array during the first minute after Mike Hour.

ARKANSAS (BB-33) sank within a few seconds after Mike Hour, while still obscured by spray and steam. She was crushed as if by a tremendous hammer blow from below.

YO-160 (concrete oil barge) was seen in photographs taken immediately after Mike Hour and had disappeared when the base surge had passed. She was swamped by the outrushing wall of water.

PILOTFISH (SS-386) (submerged at a keel depth of approximately 56 ft) is believed to have sunk immediately after Mike Hour according to evidence obtained by divers and underwater photography.

SKIPJACK (SS-184) (submerged at a keel depth of 75 ft) was found on the bottom after Mike Hour with her hull plating cracked and several compartments flooded.

APOGON (SS-308) (submerged at a keel depth of 100 ft) was found on the bottom after Mike Hour, with holed bulkheads at several frames and with practically all compartments flooded.

SARATOGA (CV-3) sank by the stern approximately 7½ hr after Mike Hour. The appearance of the shell at the turn of the bilge indicates that she probably suffered very severe damage along the bottom and along the starboard side.

NAGATO (EX-JAP BB) with her hull holed in numerous places, sank during the night of 29-30 July, four days after B-Day.

Chapter 21

Summary of Results of Test B

Outline

Chapter 21

Summary of Results of Test B

21.001 Introduction.

Bomb B detonated 90 ft below the surface of Bikini Lagoon at 59.7 sec (± 0.1 sec) after 0834, 25 July 46, Bikini Local Time. Seventy four target vessels were exposed to the explosion; their positions were as shown in Table 20.1 of Chap. 20.

21.002 Energy Release.

The amount of energy released was "normal" for an atomic bomb of the Nagasaki type; a total of 8.5 X 10^{20} ergs of energy was released, which is equivalent to the total amount of energy released in the exploding of 20.3 kilotons of TNT.

21.003 Damage to Vessels.

A total of 9 vessels sank or capsized as a result of the explosion; they were situated in the range: 0 to 845-yd horizontal distance from the projected Zeropoint. (Distances are measured to nearest point of vessel.) Five (non-sunk) vessels were immobilized; they were situated at ranges from 465 yd to 640 yd.

Three other vessels, at ranges of 815 to 1030 yd, suffered at least temporary serious loss of military efficiency.

21.004 Other Damage.

Moderate damage was inflicted on a B-17 drone flying 6000 ft directly above the Zeropoint.

Special radio and radar equipment exposed on decks of surface vessels was severely damaged at ranges as great as 700 yd. Data are lacking as to damage between 700 and 2000 yd. No important damage was suffered by deck-loaded equipment at 2000 yd or by equipment ashore at 5700 yd.

21.005 Injury to Animals and Plants.

Although the animals were all situated in interior rooms on vessels located upwind from the Zeropoint, the great majority of them had died by 1 Nov 46. In nearly all cases, cause of death was gamma radiation. Dosages received varied from 310 roentgens (BRACKEN, at 1420 yd) to 2700 roentgens (GASCONADE, at 580 yd).

Many of the fish in the northeast corner of the Lagoon were killed by the explosion.

21.006 Pressure Data.

Values of peak pressure in the water half-way between surface and bottom were 7000, 4400, 1400, and 330 psi gage at 835, 1084, 2060, and 5000-ft, respectively, horizontal distance from the projected Zeropoint. At short ranges the pressure was somewhat less just beneath the surface than at greater depth.

The underwater shock wave had a velocity not appreciably different from the normal acoustical velocity.

Peak pressure in air was 4.8 psi gage at 1000-yd horizontal distance, or about the same as would have resulted from an air burst using 4 kilotons of TNT.

21.007 Radiation and Radioactivity.

Optical radiation was negligible.

Nuclear radiations, particularly gamma-radiation, were very important. Between 10 and 50 percent of the radioactive material formed remained in the water or on target vessels. Total activity in the area corresponded (at one hour after Mike Hour) to roughly 5×10^9 curies (5000 megacuries), the approximate momentary equivalent of roughly 5000 tons of radium. Total radioactivity diminished approximately according to a $1/T^{1.3}$ law.

The area initially contaminated extended roughly 1800 yd upwind, 2 mi to each side, and downwind for 2 to 5 mi. Near the Zeropoint, the activity in the water decreased from about 400 roentgens per 24 hrs at one hour after Mike Hour to 0.1 roentgens per 24 hrs at five days after B-Day. Convection contributed, of course, to this decrease.

All but 9 of the target vessels were highly contaminated by the

radioactive "rain" and base surge. Total gamma radiation dosages topside on the contaminated vessels ranged from roughly 300 roentgens to over 8000 roentgens. Typically, 50 percent of the dosage was "delivered" within the first 5 or 10 min; lethal dosages (400 roentgens) were delivered within 1 to 7 min in most cases.

In most (but not all) contaminated vessels, radioactivity below decks was less than ½ or even 1/10 as intense as topside.

Plutonium contamination of target vessels was sufficiently great to constitute a serious danger to persons boarding the target vessels days, weeks, or even months after B-Day (i.e., persons not already doomed by gamma radiation).

Decontamination efforts met with varying success. Earliest efforts (involving washing away loose materials) reduced the radioactivity by a factor of 2 to 5; but subsequent efforts produced smaller improvements.

Plutonium and radioactive fission products in the water were a danger to support vessels, since they tended to accumulate in evaporators and elsewhere.

21.008 Other Results.

The water directly above the bomb rose initially at a rate of 11,000 ft/sec. The height of column and cauliflower was 4100 ft at 10 sec and 7600 ft at 60 sec. Radius of the stem was 975 ft. Roughly 2,000,000 tons of water was contained in the column and cauliflower; the potential energy involved was approximately 10 percent of the total energy released in the explosion.

The condensation cloud reached its maximum radius (about one mile) at 4 sec after Mike Hour. By 30 sec it was essentially nonexistent.

The base surge formed approximately 10 sec after Mike Hour, and swept outward at 45 mi/hr, engulfing the majority of the target vessels in its radioactive mist. It attained a radius of approximately 8000 ft, and an altitude of approximately 2000 ft.

Waves had a maximum trough-to-crest height of 94 ft at a range of 1000 ft, (horizontal distance from Zeropoint), and 9 ft at 12,000 ft. The first wave travelled with a velocity of 45 knots. The waves represented less than one percent of the total energy released in the explosion.

Waves probably made significant contributions to damage on at least five target vessels.

The crater produced in the Lagoon bottom was 25 ft deep; the net amount of bottom material moved was over 2,000,000 yd^3.

The explosion was detected at great distances (e.g., Continental U. S.) by earth shock and by radioactivity in the air.

21.009 Correlations.

The following table presents estimates by the JTF-1 Technical Historian as to ranges at which specified loss of military efficiency during the first hour after Mike Hour is probable:

Extent of Immediate Loss of Military Efficiency	Range (yd)		
	Typical Ship Itself	Typical Crew Per Se	Ship and Crew in Combination
Very Serious	700	600	800
Serious	900	800	950
Moderate	1000	1000	1300
Slight	1500	2000	2000

The corresponding ranges for long term (i.e., first month) loss of military efficiency of crew per se are: 2500, 2800, 3200, and 4000 yd.

Injury may be reduced by (1) fleeing from the fall-out and base surge, (2) getting below decks, (3) designing watertight and "quick-shedding," non-porous superstructures, (4) immediately stopping pumps taking water into the ship, (5) promptly washing off exposed areas, (6) detecting and preventing access to "hottest" areas, (7) providing disposable clothing, and (8) transferring crew to uncontaminated ship as soon as possible.

Mechanical and electrical damage to vessels was caused principally by the shock wave in water, and, to a lesser degree, water waves and shock wave in air.

Gamma radiation would have been the outstanding cause of short and long term injury to crews. Topside personnel within 1700 yd would receive lethal (400 roentgens) doses within 1 to 7 min. Considerable harm would result even to personnel on vessels at 4000 yd. Only moderate protection would be afforded personnel below decks on "typical" types of vessels.

Alpha radiation from plutonium inhaled, ingested, etc., may prove

fatal over a period of years. Fifty to 100 micrograms may be a fatal dose. Dangerous concentrations may exist on contaminated vessels for months.

21.010 Discussion.

There were no technical or operational shortcomings of any significance; the Test was an entire success. The bomb was detonated at the correct time and position, and extensive graded damage was produced as desired. The instrumentation program was completed very satisfactorily; damage inspection was completed as promptly as radiological clearance permitted.

The very great importance of radioactive contamination by fission products was fully explored, and the insidious potentialities of plutonium contamination were brought to light. The Test was the world's fifth test of the atomic bomb, but it was the first test in which the radioactive "poisonous" material remained in the "biosphere," and thus presented a lingering and invisible menace to man and other forms of life.

A beginning was made at developing methods of decontamination; radioactive vessels were made available for continuing research and training in radiological decontamination, a field now known to be of prime importance.

Chapter 22

Detonation and Energy Release, Test B

Outline

Chapter 22

Detonation and Energy Release, Test B

22.001 General Appearance.

Only a brief account of the appearance of the detonation is given here. Later chapters discuss in detail the column, cloud, etc.

At 59.7 seconds (plus or minus 0.1 sec) after 0834 on 25 July, 46, Bikini local time, Bomb B was detonated, and observers approximately 10 mi away witnessed a giant and unprecedented spectacle. The column shot upward, with a small amount of orange-red light emerging for 0.2 sec. At 1 sec after Mike Hour -- long before the column had achieved its full height -- the condensation cloud began to form.

As the column and cauliflower reached their fully-developed forms, the collapse (descent) began; the column spikes began to move downward; the cauliflower periphery began to curve outward and downward, shadowing a large area of the target array.

The base surge formed as the column plunged back into the Lagoon; a wall of spray, foam, and fog swept outward at 45 mi/hr, engulfing several of the larger target vessels.

After gravity had drained most of the water from the column and cauliflower, a mass of fog and murk lay over the area, obscuring the majority of the target vessels.

The wind slowly carried this mass to the northwest, and for over an hour it could be followed readily by the eye, as a slightly-orange-tinted cloud. Within 2 hr the cloud could no longer be distinguished from the normal clouds dotting the horizon.

Within a few minutes of Mike Hour white lines (bomb-produced surf) on beaches and reefs were apparent to the naked eye of the observers, 10 mi away.

The target area appeared almost entirely clear of clouds and murk by 1 hr after Mike Hour.

22.002 Total Energy Release.

The best value for the total amount of energy released by the explosion is 8.5×10^{20} ergs, which corresponds to the total amount of energy released in the explosion of 20.3 kilotons of TNT. The figure is based on the radiochemical method described in Chap. 5. The probable error is: plus 2 percent, minus 3 percent.

22.003 Partial Energy Release.

Collateral values of equivalent-TNT-tonnage are given below. They are not ordinarily strictly indicative of the total amount of energy released. Their significance is discussed in Chap. 5 and also in Refs. 500 and 300-4.

Parameter Measured	Type of Gage Used	Equivalent-TNT-Kilotons	Source (Ref.No.)
Pressure in Water	Ball Crusher	15 to 20	300-4
Pressure in Air	Foil	4	300-4
Pressure in Air	Diaphragm Strain	4	300-4
Pressure in Air	Airborne Condenser	12	300-4
Duration of Chain Reaction Gamma Timing		"normal"	300-23
Column radius	Camera	9	300-27

22.004 Utilization of Energy.

No comprehensive information is available as to the utilization or apportioning of the energy transmitted in the optical radiation, nuclear radiation, shock wave, or existing as heat.

Chapter 23

Damage to Vessels, Test B

Outline

Section

Chapter 23

Damage to Vessels, Test B

23.001 Introduction.

This Chapter includes a brief discussion of the significant damage suffered by the principal target vessels in Test B. (For a detailed and comprehensive description of damage see Ref. 420-4.)

Distance figures included are in each case the horizontal distance of the projected actual Zeropoint from the nearest point on the vessel.

Generalizations as to range and damage severity are provisional; they are estimates by the JTF-1 Technical Historian. They have been discussed with BuShips representatives, but are not necessarily endorsed by them.

Damage caused by flooding that would easily have been prevented by the ship's force is not here regarded as damage properly attributable to the explosion.

Similarly, damage which was primarily the result of damage produced in Test A is not considered to be damage properly attributable to Test B; such damage is alluded to only for general information.

Radioactive contamination of vessels is not considered damage to vessels, and is not discussed in this Chapter. (See, however, Chap. 29.)

23.002 Loss of Military Efficiency in Test B.

A. Very Serious Loss of Military Efficiency.

1. Ships Sunk or Capsized. Nine vessels (including the bomb carrier LSM-60) were sunk or capsized in Test B. The vessels were:

Vessel	Horizontal Distance from Zeropoint (yd)
LSM-60 (bomb carrier)	0
ARKANSAS (BB-33)	225
PILOTFISH (SS-386)	260

Vessel (con't)	Horizontal Distance from Zeropoint (yd)
SARATOGA (CV-3)	350
LCT-1114	485
YO-160	425
NAGATO (ex-Jap-BB)	745
SKIPJACK (SS-184)	800
APOGON (SS-308)	845

2. Ships Immobilized. Other ships immobilized were:

FALLON (APA-81)	465
GASCONADE (APA-85)	580
HUGHES (DD-410)	635
PENSACOLA (CA-24)	640
LST-133	630

B. Serious Loss of Military Efficiency. Other ships suffering serious loss of military efficiency were:

Vessel	Horizontal Distance from Zeropoint (yd)
MAYRANT (DD-402)	815
NEW YORK (BB-34)	820
NEVADA (BB-36)	1030

Most ships within 900 yd suffered serious loss of military efficiency due to damage to electronic equipment; most ships within 800 yd suffered additional loss of military efficiency due to damage to ordnance equipment.

C. Moderate Loss of Military Efficiency. In general, surface vessels at ranges of 900 to 1100 yd suffered moderate loss of military efficiency. The chief contributing cause of loss of military efficiency in this range was damage to ordnance and electronic equipment.

D. Slight Loss of Military Efficiency. In general, damage to ordnance and electronic equipment caused slight loss of military efficiency out to approximately 1500 yd.

E. Range versus Loss of Military Efficiency. The ranges given below for various specified degrees of loss of military efficiency are such that, at the horizontal range given, it is probable (probability greater than 50 percent) that a surface vessel of unspecified type and orientation will suffer (at least temporarily) the indicated

degree of loss of military efficiency.

Extent of Short or Long Term Loss of Military Efficiency	Range (yd)
Very serious	700
Serious	900
Moderate	1000
Slight	1500

23.003 Damage to Hulls.

A. Introduction. This Section discusses damage to hulls, here considered to include decks, sides, bottoms, and superstructures of vessels.

B. Description of Damage.

1. Battleships. ARKANSAS (225 yd), battleship closest to the actual Zeropoint, received very extensive hull damage; large holes were made, and she flooded immediately and sank within one minute. Her sideshell plating gave at numerous points, rivets failing at seams and butts. Her bottom was badly indented (6 or more feet at some points). Her rudder and screw were lost. Her sides above the waterline showed little or no damage. NAGATO (745 yd) sank in 4½ days with a hole 2 ft in diameter above her port bilge keel and 7 other major leakage points. NEW YORK (820 yd) suffered moderate hull damage; she had open seams in her underwater shell plating and in three of her tanks. There was minor flooding. Holding-down clips were fractured on three of her turrets. NEVADA (1030 yd) experienced minor dishing of her hull; the holding-down clips on one turret were sheared. The remaining battleship, PENNSYLVANIA (1105 yd), received no significant hull damage.

2. Cruisers. PENSACOLA (640 yd) received moderate hull damage. This damage was confined largely to areas where her hull structure had been weakened in Test A. She suffered dishing of shell plating and damage to holding down-clips, battery mounts, bulkheads, stanchions, and machinery foundations. SALT LAKE CITY (1120 yd) suffered only minor hull damage. PRINZ EUGEN (1990 yd) was undamaged.

3. Destroyers. HUGHES (635 yd), destroyer nearest the actual Zeropoint, suffered major structural damage involving flooding due to ruptured piping and fractured sea connections. Her shell plating was slightly dished, rudder and skeg were severely damaged, and the foundation supporting one end of the low-pressure turbine was distorted. MAYRANT (815 yd) received damage to bulkheads, stanchions and weather doors. There was minor flooding caused by broken lines. No other

destroyers suffered significant hull damage.

4. Aircraft Carriers. SARATOGA (350 yd) did not suffer severe structural distortion or hull ruptures, but probably sank from progressive flooding due to a fairly large number of leaking riveted seams. INDEPENDENCE (light-cruiser hull, 1390 yd) suffered minor dishing of her hull.

5. Submarines. PILCTFISH (260 yd), submarine closest to the actual Zeropoint, sank; nearly all compartments flooded, tops of ballast tanks were no longer tight, and the superstructure was dished in. SKIPJACK (800 yd) sank; she had a crack in her athwartship plating on top of torpedo room, tops of ballast tanks leaked, and forward battery and control rooms were flooded. APOGON (845 yd) sank with most of her compartments flooded or partially flooded. There were openings in her bulkheads, hatch cover failed, and a tank top was ruptured. None of the surviving submarines received significant hull damage.

6. Attack Transports. FALLON (465 yd), APA closest to the actual Zeropoint, survived. However, she was flooded to her waterline, suffering severe structural damage to the ship girder. There was buckling of her shell and decks and a permanent transverse-curvature twist in her hull. GASCONADE (580 yd) also suffered loss of longitudinal strength. There was wrinkling in her shell and bottom, and considerable dishing of doors. In addition she experienced partial flooding from broken lines. (Flooding could have been controlled.) BRULE (865 yd) also suffered minor flooding from broken lines but there was no damage to her strength hull. There was some dishing of bulkheads. BRISCOE (880 yd) experienced light dishing of her hull. No other APA's received hull damage.

7. Other Craft. LST-133 (630 yd) suffered minor hull damage and flooding; her ballast tanks were cracked. LST-52 (1545 yd) was unaffected.

LCT-1114 (485 yd) capsized. LCT-816 (800 yd) experienced moderate dishing and flooding from undetermined cause (probable cause: opening of shell seams in engine spaces). LCT-818 (1370 yd) was unaffected.

YO-160 (425 yd) sank almost immediately. YOG-83 (1090 yd) suffered no hull damage.

ARDC-13 (1215 yd) sank due to hull damage experienced in Test A.

C. Loss of Military Efficiency.

1. Battleships. ARKANSAS (225 yd) sank immediately after the

explosion. NAGATO (745 yd) sank approximately $4\frac{1}{2}$ days after the explosion. (It is possible that with ship's force available NAGATO could have been saved.) NEW YORK (820 yd) suffered some loss of watertightness and seaworthiness from minor flooding. (Other flooding affecting her electrical steering could have been controlled by her ship's force.) NEW YORK's military efficiency was seriously impaired due to inoperability of three turrets resulting from failure of holding down clips. Likewise, the military efficiency of NEVADA (1030 yd) was moderately reduced by turret damage. The military efficiency of PENNSYLVANIA (1105 yd) was not impaired by hull damage.

2. Cruisers. PENSACOLA (640 yd) suffered moderate loss of seaworthiness due to significant structural damage to her hull. She suffered serious loss of military efficiency as the result of damage to three of her turrets rendering them inoperable. The military efficiency of SALT LAKE CITY (1120 yd) was not appreciably impaired by hull damage.

3. Destroyers. HUGHES (635 yd) suffered serious loss of military efficiency due to hull damage. Failures of piping, sea connections, and hull fittings caused some loss in buoyancy, stability, and watertightness. Her main machinery was made completely inoperable due to failure of supporting foundations. MAYRANT (815 yd) experienced no serious loss of military efficiency. (She suffered damage to machinery and electrical equipment as the result of flooding which could have been controlled by the ship's force.)

4. Aircraft Carriers. SARATOGA (350 yd) sank in 8 hr. The military efficiency of INDEPENDENCE (1390 yd) was not significantly impaired by hull damage.

5. Submarines. PILOTFISH (260 yd), SKIPJACK (800 yd), and APOGON (845 yd) sank due to hull damage. No other submarine suffered loss of military efficiency due to hull damage.

6. Attack Transports. FALLON (465 yd) suffered serious loss of military efficiency as the result of serious hull damage. GASCONADE (580 yd) also suffered serious loss of military efficiency due to loss of longitudinal strength. Her seaworthiness was greatly affected. The military efficiency of BRULE (865 yd) was not affected by hull damage.

7. Other Craft. LST-133 (630 yd) suffered moderate reduction in military efficiency due to damage to main deck and interior compartments. LCT-1114 (485 yd) sank. LCT-816 (800 yd) suffered serious loss of military efficiency; her stability was adversely affected; flooding occurred requiring beaching. YO-160 (425 yd) sank.

D. Distance versus Damage Relationship. The Test-B distance versus hull-damage data are presented in Table 23.1. The distances given are (as elsewhere in this Chapter) horizontal distances in yards from the pro-

jected actual Zeropoint to the nearest part of the vessel. In most cases the distance figure given represents the greatest radius* at which damage of indicated severity actually occurred to target vessels on B-Day. In the "Negligible Damage" columns, however, the value given for each type of vessel is the range of that vessel (suffering negligible damage) which was nearest the Zeropoint. Similarly the "Nearest Surviving Ship" column gives for each type of ship the range of that (surviving) ship which was nearest the Zeropoint. In using the Table, it is convenient to bear this rule in mind: when comparing vulnerability of ships of different type (with respect to damage of specified type and severity), or when comparing vulnerability of different parts of a ship, higher numbers indicate greater vulnerability.

E. Ship Type versus Damage Relationship. Although no reliable conclusions had been reached by 1 Nov 46 as to the relative vulnerabilities of hulls of vessels of different types, there is evidence that battleship hulls are least vulnerable and some suggestion that cruiser hulls are slightly more vulnerable than hulls of destroyers and attack transports. Submerged submarines are relatively vulnerable.

Range of "probable" major hull damage for a surface combatant vessel of "typical" type was approximately 625 yd. Other than battleship NAGATO (745 yd), no ships suffered damage classified as moderate. The range of "probable" minor hull damage for a surface vessel of "typical" combatant type was approximately 950 yd.

F. Engineering Consequences of Damage. In most cases of hull breaching, flooding occurred, causing sinking or damage to machinery and electrical equipment. Other consequences of hull damage were inoperability of machinery caused by damaged machinery foundations, inoperability of propulsion machinery, inoperability of turrets, damage to electrical wiring and electrical equipment, and damage to ordnance equipment.

G. Mechanism Producing Damage. Hull damage was caused by underwater shock, violent motion and impact caused by water waves and air blast.

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* Footnote: If the "sample" of ships had been greater, instances would presumably have occurred where even greater ranges could have been found for damage of specified type. On the other hand, we may now have instances where ships at lesser ranges did not suffer damage of the indicated severity. Thus the ranges here presented are not intended to be ranges for which the probability value equals 50 percent or any other percentage; they are merely observed greatest ranges. On the other hand, they are probably fairly close, in many cases, to "probability-equals-50 percent" ranges given in other sections.

23.004 Damage to Boilers and Stacks.

A. Introduction. Boiler damage in Test B was limited principally to brickwork, boiler foundations, and casings. There was little stack damage. In all cases of boiler damage mentioned in this Section, there was loss of boiler power.

B. Description of Damage.

1. Battleships. NEW YORK (820 yd) suffered very little damage to boilers other than to the boiler casings. Two of her boilers were made temporarily inoperable due to blown out boiler casings. Minor boiler damage occurred on NEVADA (1030 yd) and PENNSYLVANIA (1105 yd).

2. Cruisers. All boilers on PENSACOLA (640 yd) were severely damaged, both brickwork and casings being affected. SALT LAKE CITY (1120 yd) suffered only slight boiler damage.

3. Destroyers. All boilers on HUGHES (635 yd) were seriously damaged. MAYRANT (815 yd) received only minor boiler damage.

4. Aircraft Carriers. INDEPENDENCE (1390 yd) suffered no significant boiler damage. Her temporary stacks, constructed after Test A, were seriously distorted.

5. Attack Transports. FALLON (465 yd) received severe boiler damage. Her boiler foundations were severely stressed and her air casings were ruptured. GASCONADE (580 yd) suffered damage to her boiler brickwork but no damage to boiler casings. No other APA's received significant boiler damage.

C. Loss of Military Efficiency.

1. Introduction. In general, boiler damage resulted in loss of power accompanied by reduced speed and impaired operation of ship's machinery and ordnance, involving serious loss of military efficiency.

2. Battleships. NEW YORK (820 yd) suffered serious loss of military efficiency due to partial loss of boiler power; her speed would have been reduced to approximately 18 knots for a few hours. Boiler damage on PENNSYLVANIA (1105 yd) was not sufficient to prevent steaming. NEVADA (1030 yd) suffered no appreciable loss of military efficiency due to boiler damage.

3. Cruisers. PENSACOLA (640 yd) was immobilized due to boiler damage. Extensive repairs to casings and brickwork would have been required before she could have steamed. SALT LAKE CITY (1120 yd) suffered no impairment of military efficiency as the result of boiler damage.

4. Destroyers. HUGHES (635 yd) suffered serious loss of military efficiency; she was immobilized due to boiler damage. Very extensive repairs would have been required before she could have steamed. MAYRANT (815 yd) suffered no appreciable loss of military efficiency due to boiler damage.

5. Aircraft Carriers. INDEPENDENCE (1390 yd) suffered no loss of military efficiency due to boiler damage.

6. Attack Transports. FALLON (465 yd) suffered serious loss of military efficiency; she was immobilized due to boiler damage. Extensive repair would have been required on these boilers before they could steam again and complete replacement of one of her boilers might have been required. GASCONADE (580 yd) also suffered serious loss of military efficiency; she was probably immobilized due to boiler damage. It is doubtful whether her boilers could have continued operating without replacement of the floor bricks. No other APA's suffered loss of military efficiency as a result of boiler damage.

D. Distance versus Damage Relationship. The distance versus boiler damage data are presented in Table 23.1.

E. Ship Type versus Damage Relationship. It is tentatively suggested that boiler vulnerability of different types of target ships increased in the following order: attack transports (least vulnerable), destroyers and cruisers (about the same), battleships (most vulnerable). The range of "probable" major boiler damage for the above ship types was approximately 625 yd.

F. Engineering Consequences of Damage. Boiler damage was accompanied by loss of power for propulsion and operation of ships' machinery and ordnance.

G. Mechanism of Producing Damage. The boiler damage was caused by the underwater shock transmitted to the boilers through the ships' structures and by air pressure entering the boilers furnaces through the stacks and uptakes. The most serious boiler damage was caused by the underwater shock.

23.005 Damage to Miscellaneous Machinery.

A. Introduction. Damage to main propelling machinery and auxiliary machinery was extensive out to approximately 650 yd. Particularly vulnerable were propelling machinery, steering system, and diesel generators.

TOP SECRET

TABLE 23.1. GREATEST RANGE AT WHICH DAMAGE OF INDICATED SEVERITY WAS PRODUCED IN TEST B.
(Range is horizontal distance in yards from projected zeropoint to nearest part of ship.)

SHIP TYPE AND DISTANCES	SUNK	NEAREST SURVIVING SHIP OF SAME TYPE	HULL (INCLUDING SUPERSTRUCTURE)				BOILERS AND STACKS		MISCELLANEOUS MACHINERY		ELECTRICAL		
			MAJOR DAMAGE	MODERATE DAMAGE	MINOR DAMAGE	NEGLIGIBLE DAMAGE	MAJOR OR MODERATE DAMAGE	MINOR OR NEGLIGIBLE DAMAGE	MAJOR OR MODERATE DAMAGE	MINOR OR NEGLIGIBLE DAMAGE	MAJOR DAMAGE	MODERATE DAMAGE	MINOR OR NEGLIGIBLE DAMAGE
BATTLESHIPS 225, 745, 820, 1030, 1105	745 (NAGATO)	820 (NEW YORK)	225 (ARKANSAS)	745 (NAGATO)	1030 (NAGATO)	1105 (PENNSYL-VANIA)	820 (NEW YORK) (MODERATE)	1105 (PENNSYL-VANIA)	--	1105 (PENNSYL-VANIA)	NO CASES	820 (NEW YORK)	1030 (NEVADA)
CRUISERS 640, 1120, 1390	NO CASES	640 (PENSACOLA)	640 (PENSACOLA)	NO CASES	1120 (SALT LAKE CITY)	1390 (INDEPEN-DENCE)	640 (PENSACOLA) (MAJOR)	1120 (SALT LAKE CITY)	640 (PENSACOLA) (MAJOR)	1120 (SALT LAKE CITY)	NO CASES	640 (PENSACOLA)	1120 (SALT LAKE CITY)
DESTROYERS 635, 815, 1280	NO CASES	635 (HUGHES)	635 (HUGHES)	NO CASES	815 (MAYRANT)	1280 (MUSTIN)	635 (HUGHES) (MAJOR)	815 (MAYRANT)	635 (HUGHES)	1280 (MUSTIN)	635 (HUGHES)	NO CASES	1280 (MUSTIN)
AIRCRAFT CARRIERS, LIGHT 1390	NO CASES	NO CASES	NO CASES	NO CASES	NO CASES	1390 (INDEPEN-DENCE)	NO CASES	1390 (INDEPEN-DENCE)	NO CASES	1390 (INDEPEN-DENCE)	NO CASES	NO CASES	1390 (INDEPEN-DENCE)
AIRCRAFT CARRIERS, HEAVY 350	350 (SARATOGA)	NO CASES	--	--	--	--	--	--	--	--	--	--	--
SUBMARINES 260, 800, 845, 885, 1085, 1465	845 (APOGON)	885 (SKATE)	845 (APOGON)	NO CASES	NO CASES	885 (SKATE)	--	--	800 (SKIPJACK)	1465 (DENTUDA)	885 (SKATE)	NO CASES	1600 (TUNA)
ATTACK TRANSPORTS 465, 580, 865, 880, 1190	NO CASES	465 (FALLON)	580 (GASCONADE)	NO CASES	880 (BRISCOE)	1190 (DAWSON)	580 (GASCONADE) (MAJOR)	865 (BRULE)	580 (GASCONADE)	1190 (DAWSON)	465 (FALLON)	580 (GASCONADE)	1190 (DAWSON)
EXPLANATION OF COLUMN HEADINGS	--	--	BUCKLING OF PLATES AND SERIOUS FLOODING OR LOSS OF LONGITUDINAL STRENGTH	MINOR BREACHING OF HULL	DISHING OF SHELL PLATING	DISTANCE OF NEAREST SHIP SUFFERING NEGLIGIBLE DAMAGE	IMPAIRMENT OF BOILER OPERATION	MINOR OR NO DAMAGE	MACHINERY DAMAGE IMPAIRING MILITARY EFFICIENCY	MINOR OR NEGLIGIBLE MACHINERY DAMAGE	ELECTRICAL DAMAGE SERIOUSLY IMPAIRING MILITARY EFFICIENCY	ELECTRICAL DAMAGE MODERATELY IMPAIRING MILITARY EFFICIENCY	MINOR OR NEGLIGIBLE ELECTRICAL DAMAGE

B. Description of Damage.

1. Battleships. NEW YORK (820 yd) had her electric steering system, a diesel generator, and a fire pump rendered inoperative. NEVADA (1030 yd) suffered damage to her main steering unit and after diesel generator. This damage was due to flooding and would not have occurred had there been an uninjured crew aboard. PENNSYLVANIA (1105 yd) suffered only minor machinery damage.

2. Cruisers. The main propelling and auxiliary machinery on PENSACOLA (640 yd) was seriously damaged. SALT LAKE CITY (1120 yd) suffered only minor machinery damage.

3. Destroyers. The main machinery was inoperative on HUGHES (635 yd), partly due to failure of supporting foundations. Main propelling machinery on MAYRANT (815 yd) was inoperative due to minor flooding. This flooding could have been controlled by an uninjured crew. MUSTIN (1280 yd) suffered no appreciable machinery damage.

4. Aircraft Carriers. INDEPENDENCE (1390 yd) did not experience significant machinery damage.

5. Submarines. SKATE (885 yd) suffered serious damage to her main propelling and auxiliary machinery. SEARAVEN (1420 yd) did not experience significant machinery damage.

6. Attack Transports. The machinery plant on FALLON (465 yd) was rendered completely inoperable with serious damage to main propelling and auxiliary machinery. Similar serious machinery damage occurred on GASCONADE (580 yd). BRULE (865 yd) experienced minor machinery damage.

C. Loss of Military Efficiency.

1. Introduction. In all cases of major machinery damage military efficiency was seriously impaired. In general, damage to propelling machinery completely immobilized the ship.

2. Battleships. No battleships experienced serious loss of military efficiency due to machinery damage (other than boiler damage).

3. Cruisers. The military efficiency of PENSACOLA was seriously impaired by machinery damage. She suffered complete loss of propulsion and ship control. SALT LAKE CITY (1120 yd) suffered negligible loss of fighting efficiency due to machinery damage.

4. Destroyers. Military efficiency of HUGHES (635 yd) was seriously impaired due to machinery damage. Damage to main engines

left the ship completely inoperable. If one assumes that flooding on MAYRANT (815 yd) could have been controlled, then she suffered no appreciable loss of military efficiency due to machinery damage.

5. Aircraft Carrier. INDEPENDENCE (1390 yd) did not suffer impairment of military efficiency due to machinery damage.

6. Submarines. No submarines suffered serious significant loss of military efficiency due to machinery damage. However, SKATE's (885 yd) storage batteries were impaired.

7. Attack Transports. The military efficiency of FALLON (465 yd) was seriously impaired by machinery damage. GASCONADE (580 yd) also suffered serious impairment of military efficiency due to serious damage to her main propelling and auxiliary machinery. BRULE's (865 yd) military efficiency was not impaired by machinery damage.

D. Distance versus Damage Relationship. The distance versus machinery damage data are presented in Table 23.1.

E. Ship Type versus Damage Relationship. Submarines suffered at least minor machinery damage at greater range than any other ship type.

F. Engineering Consequences of Damage. In general, serious damage to main propelling and auxiliary machinery caused loss of propulsion and control.

G. Mechanism of Producing Damage. Main propelling machinery and auxiliary machinery suffered from effects of shock and violent motion of the ship. Rapid accelerations in many cases caused shearing and parting of machinery supports.

23.006 Damage to Electrical Equipment.

A. Introduction. Extensive damage to electrical equipment occurred at ranges as great as approximately 600 yd. Especially vulnerable to damage were diesel generators and master gyroscopes.

B. Description of Damage.

1. Battleships. NEW YORK (820 yd) suffered damage (from flooding) to an emergency diesel generator and electric steering motors. Both of her gyro compasses were damaged. NEVADA (1030 yd) had her main steering unit and after diesel generator flooded. This flooding would not have occurred had an uninjured crew been aboard. PENNSYLVANIA (1105 yd) suffered damage to her master gyro and loss of electrical steering gear.

2. Cruisers. PENSACOLA (640 yd) suffered damage to a diesel generator and gyro compasses. SALT LAKE CITY (1120 yd) experienced damage to gyrocompasses due to flooding which could have been controlled had her crew been aboard.

3. Destroyers. HUGHES (635 yd) experienced damage to turbogenerators. MAYRANT (815 yd) suffered damage to pump motors and gyrocompass. MUSTIN (1280 yd) did not receive significant electrical damage.

4. Submarines. Failure of battery cell ventilation on SKATE (885 yd) constituted serious electrical damage. Her master gyrocompass and its follow-up system were rendered inoperable. SEARAVEN (1420 yd) also experienced failure of her master gyrocompass and its follow-up system.

5. Attack Transports. FALLON (465 yd) suffered major damage to her generator and electrical propulsion equipment. The turbogenerator and master gyrocompass on GASCONADE (580 yd) were rendered inoperative. The electrical equipment on BRULE (865 yd) was relatively undamaged.

6. Other Craft. LST-133 (630 yd) suffered serious damage to her electrical plant due to damage to three diesel generator sets. Her gyrocompass was also inoperative. Electrical equipment on LCT-816 (800 yd) was rendered inoperative by flooding.

C. Loss of Military Efficiency.

1. Introduction. The principal effects of electrical damage on military efficiency were: loss of fire control and gunnery due to loss of gyrocompasses; loss of power due to generator damage resulting in loss of electric steering and other electric machinery.

2. Battleships. The military efficiency of NEW YORK (820 yd) was seriously impaired by electrical damage which affected fire control and gunnery. Electrical damage to NEVADA (1030 yd) and PENNSYLVANIA (1105 yd) had only slight effect on military efficiency.

3. Cruisers. PENSACOLA (640 yd) suffered slight loss of military efficiency due to inoperability of diesel generator and gyrocompass. SALT LAKE CITY (1120 yd) experienced loss of after fire control and gyrocompasses due to flooding. This flooding could have been eliminated if an uninjured crew had been aboard.

4. Destroyers. HUGHES (635 yd) suffered slight loss of military efficiency due to damage to turbogenerators. Damage to pump motors and master gyrocompass slightly impaired military efficiency of MAYRANT (815 yd). No other destroyers suffered appreciable loss of military efficiency due to electrical damage.

5. Aircraft Carriers. INDEPENDENCE (1390 yd) suffered no loss of military efficiency due to electrical damage.

6. Submarines. Electrical damage to SKATE (885 yd) in the form of battery cell damage seriously impaired her military efficiency. Only fifty percent of her "submerged power" could be realized. Failure of SKATE's gyroscope follow-up necessitated hand feeding of the course to the topside data computer. SEARAVEN (1420 yd) suffered slight loss of military efficiency due to failure of gyroscope follow-up system.

7. Attack Transports. Electrical damage reduced the military efficiency of FALLON (465 yd) to zero; there was complete loss of propulsion. GASCONADE (580 yd) experienced only slight loss of military efficiency from electrical damage.

8. Other Craft. LST-133 (630 yd) suffered serious loss of military efficiency due to loss of steering and generators. The military efficiency of LCT-816 (800 yd) was seriously impaired because of electrical damage which resulted from flooding.

D. Distance versus Damage Relationship. The distance versus electrical damage data are presented in Table 23.1.

E. Engineering Consequences of Damage. Serious damage to generators caused power failure accompanied by inoperability of all electrical equipment (electric propulsion equipment, electric steering system) lights, fire control system. Damage to master gyrocompass affected ship control.

F. Mechanism Producing Damage. Damage to electrical equipment was caused by flooding, shock, and violent motion of the ship.

23.007 Damage to Ordnance Equipment.

Serious damage to ordnance equipment occurred out to 800 yd. The heavy equipment generally received more damage than the light or medium weight equipment. Damage to holding-down clips seriously affecting turret operation occurred on PENSACOLA (640 yd), NEW YORK (820 yd), and NEVADA (1030 yd). No light weapons were made completely inoperable and the only damage to intermediate caliber guns was on the HUGHES (635 yd).

Fire control equipment received considerable damage on vessels within 700 yd of the bomb. The equipment on HUGHES (635 yd) and PENSACOLA (640 yd) was made almost completely inoperative.

Some gun directors on HUGHES, PENSACOLA, SALT LAKE CITY, and NEW YORK received serious damage.

In general, fire control radars more than 1500 yd from the detonation were undamaged while all those closer than 800 yd were rendered completely inoperable.

A sharp line of demarkation between serious and minor damage to ordnance equipment may be drawn between HUGHES (635 yd) and MAYRANT (815 yd); the former suffered very serious loss of military efficiency of ordnance equipment while the latter sustained only minor damage to ordnance equipment.

23.008 Damage to Electronic Equipment.

Electronic equipment suffered major damage on four ships, light to medium damage in approximately 15 ships, and no appreciable damage on approximately 45 ships. In general, heavy damage was confined to ranges less than 1200 yd. Medium to light damage occurred out to 1500 yd.

Shock and vibration accounted for the majority of the damage. The remaining damage was caused either by falling water from the column or by water used in decontamination.

23.009 Relationship Between Ship Orientation and Damage.

The relationship between ship orientation and damage has not yet been determined. However it is interesting to note the difference in the nature of damage to GASCONADE and HUGHES. The distances from the actual Zeropoint to the centers of these ships were approximately the same; yet GASCONADE (approximately stern-to the explosion) had her longitudinal strength seriously impaired while HUGHES (broadside) suffered little or no loss of longitudinal strength. A possible explanation of this difference is that GASCONADE suffered hogging and sagging from riding perpendicular to the waves while the HUGHES rode parallel to the waves and had her bottom supported by the water at all times.

Chapter 24

Other Damage. Test B

Outline

Chapter 24

Other Damage, Test B

24.001 Introduction.

Special equipment exposed on decks of target vessels became radioactively contaminated (by waves, column fall-out, base surge, etc.) as did the decks of the target vessels on which the equipment was exposed. The area affected and the extent of radioactivity have been described in the previous chapter.

24.002 Damage to Airborne Aircraft.

Damage to airborne aircraft in Test B was limited to the two Army B-17 drones which were almost exactly above Zeropoint at Mike Hour. These planes carried out their missions and landed safely, but were damaged as follows:

Drone	Altitude (Ft)	Slant Range (Nautical Miles)	Damage
Fox	6000	1.0	Bomb-bay doors blown in; rivets pulled through skin; front escape hatch bent; tail-cone window frame bent and window blown in; starter adapter plywood holder in radio room broken; small inspection doors on lower surface of wing blown open.
George	16,000	2.9	Plywood door between bomb-bay and radio room broken; two wing inspection doors hanging open.

According to slow-reading accelerometers possessing considerable lag, drone Fox received accelerations in the neighborhood of plus 12 and minus 6 G. (The accelerometer indicator went off-scale.) Drone George received accelerations in the neighborhood of plus 8 and minus 5 G. (The accelerometer indicator went off-scale.)

24.003 Other Damage.

Severe damage to deck-loaded radio and radar equipment was produced by the pressure wave in air and by solid water impact at distances up to 700 yd.

No operational damage was sustained by deck-loaded equipment at 2000 yd or by equipment ashore at 5700 yd.

No structural damage was sustained by rafts of bridging at 1200 yd or by an amphibious truck at 5500 yd.

No information was available on 1 Nov 46 in the Office of the Director of Ship Material as to damage suffered by special deck-loaded equipment at ranges between 700 and 2000 yd.

Chapter 25

Injury to Animals and Plants, Test B

Outline

Section

Chapter 25

Injury to Animals and Plants, Test B

25.001 Introduction.

A detailed account of injury to pigs and rats exposed in Test B is contained in Ref. 420-6. Details on injury to fish, algae, etc., are contained in Ref. 300-15.

25.002 Injury to Pigs and Rats.

Injury to pigs and rats exposed in Test B is summarized briefly in the following table: (Source: Ref. 420-6; 300-12; also tentative information received orally on 13 Nov 46 from Dr. J. L. Tullis and Dr. P. Scoville.)

Vessel	Dist. from Burst to Nearest Part of Vessel (yd)	Approximate Total Exposure (Roentgens)	Animals Exposed	Animals Recovered Alive	Animals Recovered Dead	Animals Alive 20 Aug.	Animals Alive 1 Nov.
GASCONADE	580*	2700	10 pigs	4	6	0	0
			50 rats	0	50	0	0
BRISCOE	878*	1500	49 rats	47	3	12	9
CATRON	1210*	1500	10 pigs	10	0	0	0
			50 rats	49	1	34	30
BRACKEN	1420*	310	50 rats	26	24	23	17

* upwind

These animals were situated in the surgical operating rooms of the APA's, outboard on the starboard side, two decks below the weather deck.

As indicated in the Table nearly all these animals had died by 1 Nov 46. Deaths of pigs and rats on GASCONADE, BRISCOE, and CATRON were presumably caused by gamma radiation which passed through decks and bulkheads after emanating from contaminated material falling on the vessels; neutron radiation was negligible. Deaths of the rats on

BRACKEN were probably due to destruction of water supplies in some of the cages.

When reached by reboarding teams the most seriously injured (moribund) pigs were capable of little muscular activity; they were unable to stand and were feverish. Less heavily exposed animals were muscularly weak and had diarrhea, increased respiration rate, and hemorrhagic patches on mucous membranes.

These symptoms were mainly the result of destruction of white blood corpuscles by the gamma radiation.

25.003 Injury to Other Life.

The majority of fish in the Lagoon survived. Many in the northeast corner of the Lagoon were killed; many were found which had apparently been killed by the shock; and many others, dead and alive, were found to contain large quantities of accumulated radioactive material.

Concentration of radioactivity was found in corals, algae, shrimp, clams, plankton, and sea urchins. Some fish, clams, and sea urchins were believed to have died from overexposure; extensive damage was done to reef-building corals and calcareous algae by pollution by floating oil.

Minor damage to grasses and Tacca plants on the Lagoon side of Bikini Island occurred due to salt-water flooding by waves. (Source: 300-7)

Outline

Chapter 26

Pressure Data, Test B

Chapter 26

Pressure Data, Test B

26.001 Introduction.

Detailed accounts of pressure produced by Bomb B are contained in Ref. 300 (particularly Ref. 300-13).

26.002 Peak Pressure in Water.

Peak underwater pressures produced are listed below: (Source: Ref. 300-13)

Horizontal Distance from Projected Zeropoint (ft)	Peak Pressure just Beneath the Surface of the Water (psi gage)	Peak Pressure at Depth Half-way between Surface and Bottom (psi gage)
835	4600	7000
928	4200	5900
996	3800	5200
1084	3800	4400
1278	3000	3200
1554	2200	2300
2060	1400	1400
3040	800	800
3700	560	560
5000	330	330

By 1 Nov 46 no estimate of the probable error of these data had been made. It is well known, however, that the underwater pressure varied greatly depending on bottom reflections.

26.003 Duration of Pressure Pulse in Water.

The positive pressure pulse in water lasted one or two milliseconds. (Source: Ref. 300-13; distances and depths not specified.)

26.004 Peak Underwater Pressure Screening by Target Vessels.

Few data were availalbe by 1 Nov 46 as to the "screening" or occultation produced in the underwater pressure wave by the hulls of target vessels.

In one instance, underwater pressure on the remote side of the hull of a target vessel was only 40 percent as great as on the exposed side. (Source: Ref. 300-13; distance of vessel not specified.)

26.005 Velocity of Underwater Shock Wave.

Measured velocity of the underwater shock wave was not significantly different — even at ranges of only a few hundred feet from the Zeropoint -- from the normal acoustical velocity. (Source: Ref. 301)

26.006 Peak Pressure in Air.

Peak pressure in air (outside the column) was similar to what would have been produced by an air burst equivalent to 4000 tons of TNT. Actual values were given below: (Source: Ref. 300-13)

Horizontal Distance from Projected Zeropoint (yd)	Peak Pressure in Air (psi gage)
550	16.
650	9.6
800	6.6
1000	4.8
1200	3.8
1500	2.8

The probable error is 10 percent according to Dr. W. G. Penney, and 25 percent according to JTF-1 Technical Historian.

Chapter 27

Radiation and Radioactivity, Test B

Outline

Chapter 27

Radiation and Radioactivity, Test B

27.001 Introduction.

No detailed data are included as to the amount of optical radiation emerging from the detonation area in Test B, since the amount was negligible. It entirely escaped the notice of many observers, and is shown by high-speed photographs to have been of low intensity and short duration (of the order of 0.1 sec).

On the other hand the radioactivity in the water and on target vessels was extremely important and is discussed in the following sections.

27.002 Nature of the Radioactive Material.

The intense radioactivity in the water was due to (a) fission products, which emitted beta and gamma rays, (b) "unfished" material from the bomb, which emitted alpha rays, and (c) radioactive sodium 24, which emitted beta and gamma rays. The induced radioactivity in the hydrogen and chlorine of sea water was of no practical importance.

27.003 Total Amount of Radioactive Material.

Between 10 and 50 percent of the total amount of radioactive material produced by the explosion remained in the water. The total beta activity in the water of the Lagoon at one hour after Mike Hour was between 1.5×10^9 and 5.0×10^9 curies. On the basis of an estimated 2 to 1 ratio between beta and gamma activity, total (beta plus gamma) activity in the Lagoon at one hour after Mike Hour was between 2.3×10^9 and 7.5×10^9 curies, the approximate (momentary) equivalent of between 2500 and 8300 tons of radium.

27.004 Character of the Radiation.

Alpha particles, beta particles, gamma rays, and neutrons were present in the water of the Lagoon at and after the instant of detonation. Their origins and chracteristics were as indicated below:

A. Alpha Particles. Alpha particles emanated from atoms of "unfished" fissionable material which was widely dispersed by the detonation. They were of low energy and low penetrating power; few of them could have penetrated ordinary clothing. They represented an insignificant fraction of the total ionizing radiation present at any particular time. However, alpha radiation from unfished material entering the human body was an important hazard.

B. Beta Particles. Beta particles emanated from the various fission products of the bomb and from elements in the sea water in which artificial radioactivity was induced by neutron capture. Most of the beta particles had energies below approximately 2.3 Mev. They were not highly penetrating and were capable of inflicting little or no subcutaneous damage on personnel.

C. Gamma Rays. Gamma rays emanated from four distinct sources: (1) the bomb during the detonation process; (2) fission products; (3) atoms which were near the detonating bomb captured neutrons and at once emitted gamma rays; (4) atoms which were near the detonating bomb captured neutrons and emitted gamma rays for a long time afterwards. Gamma rays produced by processes (1), (2), and (3) were of high energy and very great penetrating power; gamma rays produced by process (4) and after the initial stages by process (2) were of lower energy and lower penetrating power. Process (2) was the chief source of gamma radiation on the target vessels and in the water. Gamma rays penetrated air, water, and flesh comparatively readily, but were considerably attenuated by appreciable thicknesses of steel.

D. Neutrons. Neutrons were emitted from the detonating bomb. Steel had little shielding effect against them; water afforded considerable shielding. The neutron flux on the target vessels was negligible since nearly all the neutrons were slowed and absorbed by the sea water.

27.005 Time-Rate of Decay of the Total Quantity of Radioactive Material.

At one hour after Mike Hour, the radioactivity near the surface of the water at Zeropoint was approximately 400 roentgens/24 hr. No single curve is available which describes accurately the time-rate of decay of the total quantity of radioactive materials. Two limiting curves exist. One, based on measurements of gamma radiation aboard target vessels, gives a rate proportional to $1/T^{1.3}$. The other is predicted on a mixture of 20 percent radioactive sodium 24 with a half-life of 14.8 hr and 80 percent fission products decaying at a rate proportional to 1/T. (Percentages are computed with respect to radioactivity.)

Presented below are illustrative values of periods in which radioactivity obeying the $1/T^{1.3}$ law diminishes by half.

Arbitrary Starting Time	Subsequent Period Required for Radioactivity to Diminish by Half
4 hr after Mike Hour	2.5 hr
10 hr after Mike Hour	7.0 hr
1 day after Mike Hour	18.0 hr
4 days after Mike Hour	2.5 days
10 days after Mike Hour	6.5 days
30 days after Mike Hour	20.0 days

27.006 Initial Area of Concentration of Radioactive Material.

Fall out from the cloud caused a "rain" of radioactive material to fall in an area extending about 1800 yd upwind from Zeropoint, almost 2 mi to each side, and downwind for several (perhaps 2 to 5) miles. A negligible amount of radioactivity existed in water outside the Lagoon.

27.007 Concentration as a Function of Depth.

The largest part of the radioactive material to remain in the Lagoon was deposited on the surface of the water by the radioactive "rain"; little, if any, radioactive material was present initially near the bottom. Vertical diffusion was very slow. In certain regions, however, downward moving convection currents produced relatively rapid vertical mixing.

The Table presented below gives the approximate amount of radioactive material in an infinite horizontal sheet of water one cm thick at the depth specified. All values are corrected to 4 hr after Mike Hour, thus eliminating the radioactive decay factor.

Day Sample was Taken	Amount (Kilocuries) at Indicated Depth: 0 ft	10 ft	75 ft	150 ft
2 days after B-Day	570	690	500	150
5 days after B-Day	430	410	190	50

27.008 Over-all Diminution of Radioactive Material in the Target Area Waters.

As an example of the over-all diminution (from all causes) of the amount of radioactivity in the target area waters, gamma radiation at

the surface of the Lagoon near the Zeropoint fell from about 400 roentgens/24 hr at one hour after Mike Hour to about 65 roentgens/24 hr by 4 hr after Mike Hour and to less than 0.1 roentgens/24 hr by five days after B-Day.

Decrease in concentration was due to: (a) radioactive decay, (b) diffusion, and (c) convection caused by wind and subsurface currents.

27.009 Radioactivity on the Bottom.

Three days after B-Day radioactivity in the Lagoon-bottom materials was less than one percent of the total radioactivity in the water.

Bottom samples from collections begun on the 6th day after B-Day, showed extremely high radioactivity in a layer of newly deposited sand and mud 4 to 8 in. thick near Zeropoint, and appreciable amounts on the bottom throughout the Lagoon. There was no evidence of activity in the bottom material underneath the new deposit.

27.010 Radioactivity on Target Vessels.

All but 9 of the target vessels were highly contaminated by the radioactive "rain" which resulted from the underwater detonation. This included all vessels within about 1800 yd upwind, 3000 yd crosswind, and more than 4000 yd downwind. Total time-integrated dosages on vessels within 1000 yd were over 8000 roentgens.

Topside personnel within 700 yd would have received lethal dosages (400 roentgens) within 30 sec to 1 min and would have received roughly 20 times the lethal dosage (8000 roentgens) within the first hour; personnel within 1700 yd would have received lethal doses within 7 min, and those within 2500 yd (crosswind or downwind) would have received lethal doses within 3 hrs.

The major part of the contaminating materials deposited on the target vessels was probably deposited from the base surge; thus the arrival of the materials was sudden, and the nuclear radiation dosages effected in the first few minutes after arrival probably were of outstanding importance.

Extrapolation of a decay curve based on later measurements indicates that radioactivity on the BRACKEN (1750 yd upwind) at one hour after Mike Hour was as high as 2500 roentgens/24 hr. By 10 days after B-Day 35 vessels still had average topside readings greater than 1 roentgen/24 hr; and by 11 days after B-Day topside intensity on BRACKEN was still 1.2 roentgens/24 hr.

In general, the most exposed locations on a given vessel were the most highly contaminated. Highest readings were obtained on superstructures and exposed decks. In many instances, small regions of especially intense radioactivity were found.

Cordage, canvas, and other porous articles were much more heavily contaminated than metallic surfaces in the same locations.

Wooden decks appeared to absorb greater quantities of radioactive material than metal ones, but the material was found to be confined to a comparatively thin surface layer.

A number of vessels were covered with contaminated coral sand which had been scoured from the bottom of the Lagoon by the explosion.

Little radioactive material penetrated into the interiors of the target vessels, since, in most cases, hatches and ventilators had been closed. Radioactivity below decks varied from 1/2 to less than 1/10 that observed topside. This radioactivity was primarily caused by material deposited on the outside and consequently decreased toward the centerline and toward the lower decks. On certain vessels, however, leakage of radioactive material did occur into the interiors through incompletely secured hatches or ports, or as a result of damage incurred in Test A. On SALT LAKE CITY, certain areas below decks gave readings as high as 20 roentgens/24 hr as late as 13 days after B-Day. Similar conditions existed on a number of other vessels.

The radioactive material accumulated on the hulls of the submerged submarines was less than that on surface vessels, since these submarines were not exposed to the radioactive "rain." However, the bitumastic on the submarine hulls showed a particular affinity for the fission products, and decontamination was extremely difficult.

27.011 Decontamination Results.

Earliest decontamination efforts succeeded in reducing the radioactivity by a factor of 2 to 5, in most cases. Loose material was relatively easily washed off.

Later decontamination efforts, made after the loose material had already been eliminated, produced much less effect. These later efforts involved scrubbing with lye, foamite, and acid, and in some small areas blasting with sand and soft grits. (Source: Ref. 300-20 Fig. 1, of Appendix VII; also Ref. 420)

27.012 Contamination of Support Vessels.

Support vessels entering contaminated areas of the Lagoon during a period of several weeks after Mike Hour collected appreciable amounts of fission products and "unfished" material. These materials were concentrated in evaporators, salt water lines, and in the organic material on the vessels' hulls. The removal of these materials, which were sufficiently concentrated to present an important hazard to personnel, constituted a serious problem.

Chapter 28

Other Detailed Results of Test B

Outline

Section

28.001 Column and Cauliflower
- A. Height of Dome, Column, and Cauliflower
- B. Radius of Column
- C. Weight of Column
- D. Energy in Column
- E. Radioactivity
- F. Demise

28.002 Condensation Cloud

28.003 Base Surge

28.004 Water Waves
- A. Height
- B. Arrival Time
- C. Velocity
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- E. First Wave versus Later Waves
- F. Range for Greatest Height
- G. Number
- H. Symmetry
- I. Waves on Bikini Beach
- J. Limit of Range
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28.005 Bottom Phenomena

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Chapter 28

Other Detailed Results of Test B

28.001 Column and Cauliflower.

A. Height of Dome, Column and Cauliflower. Water rose rapidly at first -- initially at a rate of 11,000 ft/sec. (Source: Ref. 301) The increase in height continued as indicated below:

Time after Start of Growth of Column (sec)	Height of Column and Cauliflower (ft)
0	0
1.0	2100
2.0	2900
3.0	3400
4.0	3700
5.0	3800
10.0	4100
30.0	5700
60.0	7600

B. Radius of Column. The radius of the base or stem of the column increased rapidly, and then remained nearly constant at approximately 975 ft. (Source: Ref. 510-1)

The radius of the cauliflower (crown) was 2400 ft at 5 sec, and 4300 ft at 60 sec. (Source: Ref. 510-1)

C. Weight of Column. The amount of Lagoon water, spray, and vapor comprising the column and cauliflower was approximately 2, 000, 000 tons. This value may have a probable error corresponding to a factor of 2. (Source: Ref. 302)

This weight of water corresponds roughly to 6×10^7 ft^3 or to the amount of water in a cylinder 1000 ft in radius and 20 ft in height. It corresponds also to a hollow cylinder 1000 ft in radius, 5000 ft in height, and 2 ft in wall thickness. The column contained of the order of 150 times as much water as is contained in saturated (80° F.) air occupying a volume equal to that of the column and cauliflower.

The column contained of the order of 4 ft^3 of water per 1000 ft^3 of column. (Source: Ref. 302)

D. Energy in Column. If one arbitrarily assumes that 2,000,000 tons of water was raised 1000 ft, the potential energy of the water was roughly 6 X 10^{19} ergs or roughly 10 percent of the energy released by the bomb. (Source: Ref. 302)

E. Radioactivity. Between 50 and 90 percent of the fission products remained in the cloud and surrounding air, and were carried away from the Bikini area. Ten to 50 percent of the fission products remained in the Lagoon area. (Source: Ref. 300-7)

No data were available in the Office of the Technical Director by 1 Nov 46 as to the intensity of radioactivity in the column or cauliflower.

F. Demise. The cloud remaining, after the column and cauliflower stage was terminated, drifted with the wind towards the northwest, and for over an hour the cloud could be followed readily by eye. The cloud was tinted orange. Within 2 hr after Mike Hour it could no longer be distinguished from the normal clouds dotting the horizon.

28.002 Condensation Cloud.

The condensation cloud had started forming by one second after Mike Hour; by 2.5 sec after Mike Hour it had reached the "birthday cake on a platter" stage; and by 4 sec after Mike Hour it had reached its maximum size (radius of roughly one mile).

By 18 sec after Mike Hour it had become ring-formed, then stratified and broken up into small fragments; and by 30 sec after Mike Hour it was essentially non-existent. (Source: Ref. 510-1)

28.003 Base Surge.

At about 10 sec after Mike Hour, as the column water began to plunge back into the Lagoon, the base surge, or toroidal region of spray, foam, and air formed about the base of the column. It swept and billowed outward at 45 mi/hr, engulfing the majority of the target vessels. It attained a thickness (altitude) of approximately 2000 ft, and an outer radius of approximately 8000 ft. Presumably, it was highly radioactive. (Source: Ref. 510-1)

28.004 Water Waves.

A. Height. Maximum height (trough to crest) of waves was as indicated below: (Source: Ref. 300-16)

Horizontal Distance from Zeropoint (ft)	Maximum Height (ft)
1000	94
2000	47
4000	24
6000	16
8000	13
10,000	11
12,000	9

B. Arrival Time. Arrival times of the first wave at various distances were as follows:

Horizontal Distance from Zeropoint (ft)	Arrival Time (Sec after Mike Hour)
1000	7
2000	20.5
4000	47.5
6000	75
8000	102
10,000	129
12,000	156

C. Velocity. At distances of 1000 to 12,000 ft from the Zeropoint the first wave travelled with a velocity of roughly 45 knots, the velocity expected for a long wave in water 170 ft deep. Velocities of subsequent waves were less. Velocities decreased as the waves entered shallow water.

D. Stability. Near the Zeropoint, the first (highest) wave was unstable, i.e., breaking; farther out, it was stable. On reaching shallow water as at Bikini beach, it became shorter and higher, and thus again became unstable and broke.

E. First Wave versus Later Waves. The first wave proceeded essentially as a solitary wave; at ranges greater than 700 ft its height decreased inversely with distance from the projected Zeropoint. Within 8000 ft of the Zeropoint this wave was higher than any other

wave in that area.

Just outside the 8000-ft range the second wave was higher than the first; at somewhat greater range, the third wave was the highest; and so on for succeeding waves, in accordance with the usual phase-velocity versus group-velocity relationship.

Heights of these later waves did not decrease as rapidly with distance as did the height of the first wave.

F. Range for Greatest Height. Greatest height of wave probably occurred at approximately 700 ft from the Zeropoint.

G. Number. Near the Zeropoint there were only three waves of appreciable height; there were 6 at a range of 12,000 ft and 14 or more at a range of 22,000 ft.

H. Symmetry. Waves were not perfectly symmetric about the Zeropoint. Lack of symmetry was presumably due to asymmetry in underwater coral heads and shoals.

I. Waves on Bikini Beach. As they entered the shallow water off Bikini beach (approximately 18,500 ft from the Zeropoint) the waves travelled slower and became steeper and higher. Maximum breaker height was 15 ft.

J. Limit of Range. Waves were not detected except at Bikini Atoll.

K. Origin. The first wave was produced by the initial outward thrust of the water. Subsequent waves existing near the Zeropoint were probably caused by the collapse of the water cavity and the subsequent formation of a mound of water at the center. The fact that there were so few measurable waves near the Zeropoint shows that the amplitude of oscillations (if any) of the central region diminished rapidly with time.

L. Energy. Less than 1 percent of the energy released in the detonation went into generation of water waves.

M. Damage Produced. Waves probably made significant contributions to the damage produced on FALLON, GASCONADE, HUGHES, PENSACOLA, and SARATOGA. Some beach erosion and island flooding resulted from waves reaching Bikini Island.

N. Transport by Waves. Inner target vessels were displaced laterally by waves through distances of the order of 100 to 200 ft.

No radioactive materials were transported to beaches by the waves.

Debris was carried inland, as far as 200 ft in some cases.

28.005 Bottom Phenomena.

A bottom crater of maximum depth 25 ft was created by the explosion. The crater had a maximum diameter of 1100 yd and a minimum diameter of 600 yd. The area over which the crater depth was more than 20 ft had a maximum diameter of 700 yd and a minimum diameter of 250 yd. This area was centered at a point more than 100 yd southwest from the Zeropoint. Variour minor "craters" of 5 to 10-ft depths were produced inside the main crater. (Source: Ref. 300-16)

Net amount of material removed from (and not returned to) the bottom crater region was 2, 200, 000 yd^3. Perhaps 500,000 yd^3 of material was removed and fell back into the crater.

A layer of sand and mud several feet thick was deposited on the bottom in the neighborhood of the Zeropoint.

An appreciable amount of material remained in suspension in the water for two weeks after the explosion.

28.006 Other Results.

A. Introduction. Many various results other than those discussed previously in this History were obtained in the Test. Some of the more interesting ones are presented very briefly below:

B. Temperature. Attempts to measure the average temperature rise produced in the Lagoon water in the center of the target array were unsuccessful.

C. Seismological Phenomena. Earth waves were picked up at many stations in the Pacific area and in Continental U. S. Amplitudes of the P wave as measured in Continental U. S. were of magnitude $5\frac{1}{2}$, on the earthquake scale and for an earthquake at similar range. (Source: Ref. 300-19)

Seismic vibrations had an amplitude of two millimeters and a period of 0.3 sec at Amen Island, 8 mi from the Zeropoint. The total energy in the seismic vibrations at this distance was between 10^{15} and 10^{16} ergs. (Source: Ref. 300-16)

D. Tidal Waves and Tsunamis. No tsunamis or abnormal tides were produced.

E. Magnetic Phenomena. No magnetic phenomena were detected.

F. Ionization Phenomena. No definite evidence was obtained of ionization phenomena.

G. Reflectivity and Conductivity Phenomena. No atmospheric reflectivity or conductivity phenomena were detected at great distances. Even locally no noteworth effects were found.

H. Radioactivity at Great Distance. Radioactivity in the air was detected several days later at several stations located thousands of miles away, to leeward.

I. Remote Detection. Remote detection was accomplished only by earth shock and by radioactivity in the air. See paragraph C above.

J. Winds Produced by Base Surge. Wind velocities as high as 25 knots occurred 3000 yd from the Zeropoint; they occurred several minutes after passage of the pressure wave in air, and probably represent continuation of the outward motion of the base surge.

Chapter 29

Correlation and Discussion of Test B

Outline

Chapter 29

Correlation and Discussion of Test B

29.001 Introduction.

This Chapter contains, first, general correlations and conclusions regarding the outcome of Test B, and second, various comments on the adequacy and success of the Test from a technical and technical-administrative point of view.

The correlations and conclusions are for the most part those of the JTF-1 Technical Historian. Most of them have not been approved, and it is expected that further study by experts will lead to minor changes in the correlations and conclusions. The tentative findings presented here are intended (1) to give a rough over-all picture of the outcome of the Test, and (2) to serve as a basis of discussion.

29.002 Loss of Military Efficiency of Ships.

A. Introduction. A rough but simple definition of military efficiency of a ship itself is included in Appendix III.

B. Immediate Loss. Fig. 29.1 shows the range (estimated by the JTF-1 Technical Historian) at which specified extent of immediate (i.e., first hour) loss of military efficiency of ships themselves is probable (probability equal to 50 percent). Ranges are horizontal distances from the projected Zeropoint. Estimates apply to a U. S. surface combatant vessel of unspecified type.

The following data are tentatively proposed:

Range for very serious immediate loss	700 yd
Range for serious immediate loss	900 yd
Range for moderate immediate loss	1000 yd
Range for slight immediate loss	1500 yd

C. Long Term Loss. It is not possible to make useful estimates as to the long term loss of military efficiency of ships themselves as a result of mechanical and electrical damage. Even serious loss of military efficiency from such cause may be corrected in hours or days in some cases, especially if the ship is very close to a repair yard; yet even small loss of military efficiency of the ship itself may take months to correct, if the damage is deepseated and if the

ship is far from base.

Considering "contamination" damage (including contamination by plutonium) as well as mechanical and electrical damage, it is clear that ships at ranges as great as roughly 1500 yd (in an unspecified direction with respect to wind direction) may be uninhabitable for months, unless some very effective decontamination measures are taken.

D. Weakest Link. There is perhaps no outstanding "weakest link" as regards immediate loss of military efficiency from mechanical and electrical damage; hulls, turrets, miscellaneous machinery, and electrical equipment were of comparable vulnerability.

29.003 Loss of Military Efficiency of Crews.

A. Introduction. A rough but simple definition of efficiency of a crew per se is included in Appendix III.

B. Immediate Loss. Fig. 29.1 shows the range (estimated by the JTF-1 Technical Historian) at which specified extent of immediate (i.e., first hour) loss of military efficiency of crews per se would be probable (probability equal to 50 percent). (Normal 1945 shielding is assumed; also "typical" type and orientation of ship.) The tentatively proposed ranges of interest are:

Range for very serious immediate loss of efficiency	600 yd
Range for serious immediate loss of efficiency	800 yd
Range for moderate immediate loss of efficiency	1000 yd
Range for slight immediate loss of efficiency	2000 yd

C. Long Term Loss. Tentative proposals as to ranges for long term loss (of indicated severity) of military efficiency of crews per se are:

Range for very serious long term loss	2500 yd
Range for serious long term loss	2800 yd
Range for moderate long term loss	3200 yd
Range for slight long term loss	4000 yd

However, the tactical significance of these figures is questionable since it would often be possible to replace the crew within a few weeks.

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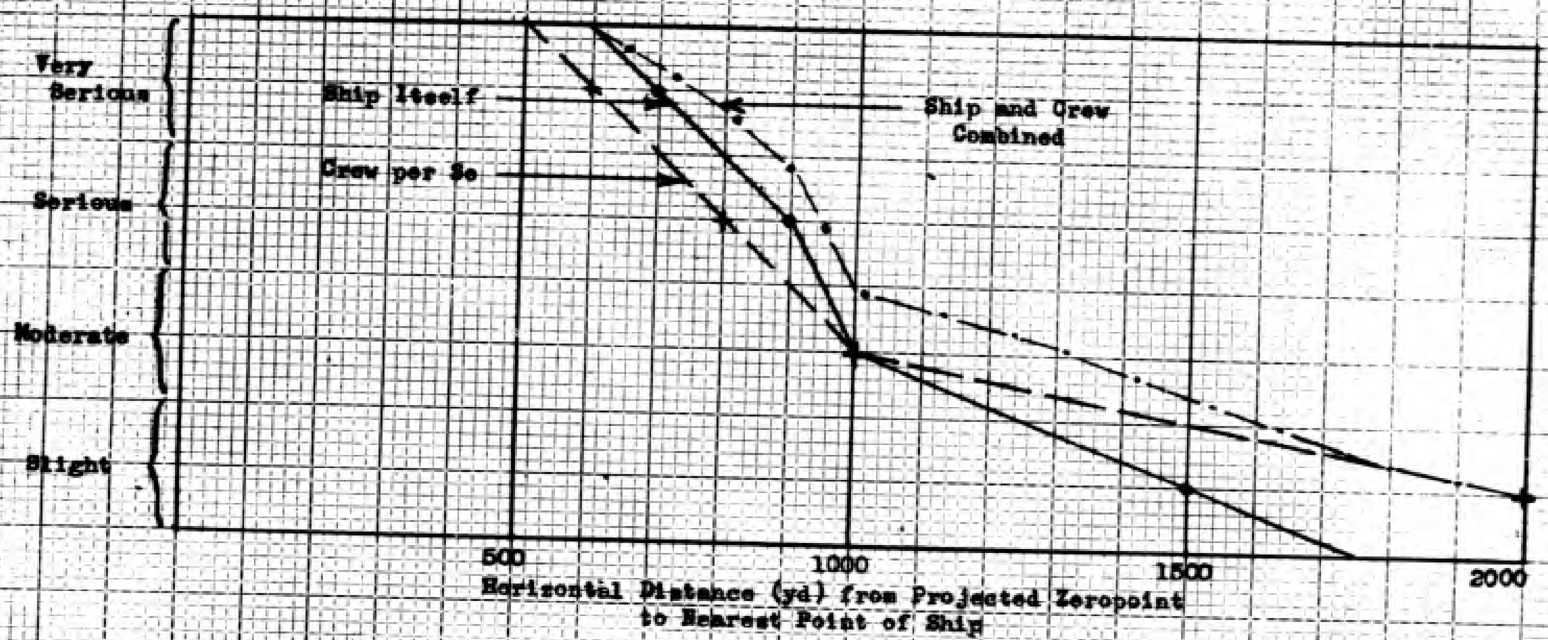

Fig. 29.1 Immediate Loss of Military Efficiency versus Range, Test B.

Source: Estimates by JTF-1 Technical Historian

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29.004 Loss of Combined Military Efficiency.

A. Introduction. For simplicity, the abbreviation CME is used below for "combined military efficiency." A rough but simple definition of combined military efficiency is included in Appendix III. The term refers, of course, to the efficiency of ship and ship's crew, considered in combination.

B. Immediate Loss. Fig. 29.1 shows the range (estimated by the JTF-1 Technical Historian) at which specified extent of immediate (i.e., first hour) loss of combined military efficiency would be probable (probability equal to 50 percent).

The tentatively proposed ranges of interest are:

Range for very serious immediate loss of CME	800 yd
Range for serious immediate loss of CME	950 yd
Range for moderate immediate loss of CME	1300 yd
Range for slight immediate loss of CME	2000 yd

C. Long Term Loss. Long term loss of combined military efficiency would be very serious for typical combatant surface vessels which are located at ranges as great as roughly 1500 yd (in an unspecified direction with respect to wind direction); unless effective decontamination measures were taken, the loss of efficiency might last for months.

29.005 Decreasing the Ranges of Loss of Military Efficiency of Ships.

No simple method suggests itself for appreciably decreasing the ranges of immediate loss of military efficiency of vessels suffering mechanical or electrical damage. Presumably thoroughgoing redesign would be required; probably any major strengthening of the vessels would entail increased weight and decreased speed.

29.006 Decreasing the Ranges of Loss of Military Efficiency of Crews.

In the search for means of decreasing the ranges or extents of immediate loss of military efficiency of crews per se the following procedures may deserve study: (1) quitting the area at full speed upwind or crosswind; (2) keeping or at least immediately bringing personnel below decks (preferably behind considerable thicknesses of steel); (3) designing superstructures so that little or no water can enter and so that practically all the water falling onto the vessel runs off immediately (i.e., eliminating undrained corners, open

lifeboats, crevices, and porous materials such as rope, canvas, wood); (4) immediately stopping pumps taking water into the ship; (5) providing prompt means of washing off all exposed surfaces; (6) providing Geiger counters for determining what areas are "hot," and preventing access to such areas; (7) providing disposable shoes, gloves, coveralls, etc., for personnel who must work in "hot" areas. Measures to strengthen morale might be required also.

Of course, personnel should be taken off "hot" vessels as soon as feasible and given appropriate medical care.

29.007 Decreasing the Ranges of Loss of Combined Military Efficiency.

Perhaps the only relatively simple methods for appreciably reducing the ranges or extents of loss of combined military efficiency are the methods described in the previous sections.

29.008 Ranges of Damage or Injury Production by Causative Factors.

A. Introduction. No final analyses have been made as to relative importance of the various causative factors. However, the following tentative analysis may be of value as a basis for discussion.

B. Shock Wave in Water. Shock wave in water probably accounts for the major part of the mechanical damage produced in vessels themselves. The shock wave in water is likely to be lethal to ships within 600 yd (at which radius the peak underwater pressure is 1700 psi gage).

C. Water Waves. Water waves probably produce a small but significant fraction of the mechanical damage to surface vessels within 700 yd, at which radius the wave height from trough to crest is 45 ft.

D. Shock Wave in Air. The shock wave in air probably causes appreciable damage to vessels (and would probably cause, including primary and secondary effects, extensive injury to personnel) situated within 800 yd, at which radius the peak pressure in air is 6.6 psi gage.

E. Gamma Radiation. Gamma radiation would be the principal cause of short term and long term injury to personnel aboard target vessels within 4000 yd at Mike Hour. Topside personnel within 700 yd would receive lethal dosages (400 roentgens) within 30 sec to 1 min and would receive roughly 20 times the lethal dosage (8000 roentgens)

within the first hour; personnel within 1700 yd would receive lethal dosages within 7 min, and those within 2500 yd (crosswind or downwind) would receive lethal dosages within 3 hrs.

Personnel situated below decks on well closed ships would receive only 1/2 to less than 1/10 the dosages received by topside personnel. (As indicated in Chap. 19, gamma radiation intensity is reduced to 50 percent by a 2-cm thickness of steel, and to approximately 1 percent by a 14-cm thickness of steel.)

(Note: According to some very recent analyses, the thickness of steel required to halve the intensity of gamma radiation may be considerably greater than 2 cm, and the intensity of radiation penetrating a considerable thickness of steel may be far greater than had been thought previously.)

Topside personnel within 700 yd upwind (and much greater range downwind) would suffer very serious loss of military efficiency within the first hour after Mike Hour, and even below decks personnel in the same area would suffer serious or moderate immediate loss of military efficiency. Even at 2000 yd, topside personnel would receive considerably more than the lethal dosage and would thus lose some military efficiency even within the first hour.

Personnel on vessels capable of fleeing the base surge might, of course, escape the gamma radiation and other nuclear radiation. (The base surge moves outward at the initial rate of approximately 45 knots.)

Symptoms of injury from gamma radiation are discussed in Sec. 19.008.

Principal source of the gamma radiation on target vessels is, of course, the fission products; gamma radiation is also emitted in considerable quantity by radioactive sodium produced by neutron capture. (See Sec. 27.005.) Gamma radiation emitted from the detonating bomb itself was almost entirely stopped by 25 to 50 ft of the Lagoon water and was thus of little consequence.

The time rate of decay of gamma-radioactive materials is discussed in Sec. 27.005.

F. Beta Radioactivity. Beta radioactivity is very intense on target vessels, but is of only minor importance in view of its short range (only a few yards) in air and its extremely short range (fraction of a millimeter) in solids. It would present a hazard principally only to the exposed skin of topside personnel. Beta radioactivity is produced mainly by the fission products.

G. Alpha Radioactivity. Alpha radiation from plutonium inhaled, ingested, etc., might prove fatal over a period of years. The harmfulness of the plutonium is aggravated by its tendency to accumulate in certain crucial regions of the body. Fifty to 100 micrograms may perhaps be fatal under such circumstances. Local but very dangerous concentrations of plutonium may exist on target vessels for months. Thus, inspection personnel entering target vessels long after the gamma radiation has ceased to be a menace may eventually be affected by plutonium "poisoning" unless proper precautions were taken.

H. Neutrons. Neutrons emitted from the detonating bomb were slowed down and absorbed before penetrating more than 25 or 50 ft of Lagoon water. They are of little significance except for the radioactive isotopes they produce. (See Paragraph E above.)

29.009 Technical Shortcomings of the Test.

While there were no technical shortcomings of any relative importance, these minor imperfections deserve mention: (1) the temperature rise in the Lagoon water was not measured; (2) values of gamma radiation intensity on some of the more important vessels were "off-scale" with the result that only lower limits (8000 roentgens) were established; (3) information is meager as to the rate of decay of the radioactivity during the first few hours and days, making a number of interesting "backward extrapolations" relatively inaccurate; (4) no accurate information was obtained as to the greatest distance at which downwind vessels would be seriously contaminated; (5) a few of the "black boxes" failed to operate correctly.

29.010 General Appraisal of the Test.

The Test was an entire success from the technical as well as the operational point of view. The bomb was detonated at the correct time and position; the target vessels were in (or very close to) their specified positions and they received graded damage as desired. The instrumentation program was very successful, and damage inspection was completed as promptly as radiological clearance permitted.

The very great importance of radioactive contamination by fission products was fully explored, and the insidious potentialities of plutonium contamination were brought to light. The Test was the world's fifth test of the atomic bomb, but it was the first test in which the radioactive "poisonous" material remained in the

"biosphere," and thus presented a lingering and invisible menace to man and other forms of life.

A beginning was made at developing methods of decontamination; radioactive vessels were made available for continuing research and training in radiological decontamination, a field now known to be of prime importance.

Chapter 30

Comparison of Tests

Outline

Chapter 30

Comparison of Tests

30.001 Introduction.

The two Tests were of very different type, and are therefore difficult to compare. Furthermore no final or approved comparisons have yet been made.

Comparisons presented below have in most instances been made by the JTF-1 Technical Historian, and are intended for interim use, as bases for discussion.

30.002 Comparisons.

Aspect Compared	Test A	Test B	Remarks
Altitude or depth	518 ft above surface	90 ft below surface	
Energy release	19.1 kilotons TNT	20.3 kilotons TNT	Remarkably alike; essentially the same as the values for Trinity and Nagasaki. Energy release at Hiroshima was appreciably less.
Number of vessels wholly or partly within 1000 yd	18 (4 of these were within 500 yd)	19 (6 of these were within 500 yd)	
Number of vessels sunk	5	9	This comparison is almost irrelevant as the target arrays were dissimilar.
Number of non-sunk vessels immobilized by mechanical or electrical damage.	6	5	Same comment as above.
Injury to animals	-	-	No meaningful comparison possible.

(con't.)

Aspect Compared	Test A	Test B	Remarks
Pressure in air at 1000 yd	10.5 psi gage	4.8 psi gage	As regards pressure in air, Test B was equivalent to an air burst of 4 kilotons TNT.
Optical Radiation	very intense (See Sec. 17.002)	negligible	
Period of intense gamma radiation	99 percent of dosage was delivered within the first 10 seconds (45 percent within the first second)	the greater part within the first 5 minutes but significant amounts for many days	-
Region emitting intense gamma radiation	fireball and mushroom	column, cloud, and base surge; later, contaminated vessels and Lagoon water	-
Maximum time-integrated gamma-radiation dosage topside on target vessel at 1000 yd	1800 roentgens	Approximately 10,000 roentgens	Test-B value depended greatly on wind direction.
Effect of alpha radiation	negligible at all times	would be fatal even to persons reboarding contaminated target vessels months after the explosion. (fatalities might result from ingestion, inhaling, etc., of very small quantities of plutonium, which is alpha-radioactive.	-
Effect of neutron radiation	fatal within 450 yd even to below-deck personnel.	negligible (except indirectly through formation of radio-sodium)	-

(con't.)

Aspect Compared	Test A	Test B	Remarks
Disposition of fission products	carried away in the mushroom and cloud	10 to 50 percent remain in the target area water and vessels	The very harmful gamma radioactivity decreases according to $1/T^{1.3}$ law.
Disposition of plutonium	same as above	same as above	The harmful and insidious alpha-radioactivity diminishes very little over periods of months or years.
Horizontal range at which probability is 50 percent that a surface combatant <u>vessel itself</u> will suffer immediate (i.e., first hour) loss of military efficiency:			
Very serious loss	<u>900</u>	700	In each case the greater value (Test A versus Test B) is underlined.
Serious loss	<u>1000</u>	900	
Moderate loss	<u>1300</u>	1000	
Slight loss	1500	1500	
Same, but for <u>crews per se</u>			
Very serious loss	<u>700</u>	600	
Serious loss	800	800	
Moderate loss	900	<u>1000</u>	
Slight loss	1000	<u>2000</u>	
Same, but for <u>vessels and crews in combination</u>			
Very serious loss	<u>900</u>	800	
Serious loss	<u>1020</u>	950	
Moderate loss	1300	1300	
Slight loss	1500	<u>2000</u>	

(con't.)

Aspect Compared	Test A	Test B	Results
Same, but for long term effect on crews per se			
Very serious loss	800	2500	
Serious loss	1100	2800	
Moderate loss	1400	3200	
Slight loss	1700	4000	
Phenomena detectable at distances of thousands of miles	radioactivity in the air	earth shock and perhaps radioactivity in the air.	
Principal cause of immediate loss of military efficiency of vessels themselves.	shock wave in air	shock wave in water	-
Same but re crews per se.	within 550 yd, neutron radiation or drowning; within the annulus from 550 to 900 yd, gamma radiation; outside 900 yd, optical radiation and shock wave in air.	gamma radiation (at all ranges)	-
Same but re long term effects on crews per se.	same as above, except that gamma radiation is important even beyond 900 yd.	same as above	
Principal source of danger to persons boarding target vessels one month after Mike Hour.	fission products	fission products and plutonium	-

(con't.)

Aspect Compared	Test A	Test B	Remarks
Period in which Lagoon was dangerously contaminated	Less than one hour.	one to two weeks	Lagoon water "changes" in 1 or 2 months.
Period in which target vessels were appreciably contaminated	Less than one day, ordinarily	weeks of months	In Test B, the period can be very greatly shortened by decontamination measures.

Chapter 31

Termination of Operation

Outline

Chapter 31

Termination of Operation

31.001 Introduction.

On 10 Aug 46 Commander JTF-1 departed from Bikini. After conferring with CinCPac at Pearl Harbor, he hauled down his flag on 18 Aug 46 from the MT MCKINLEY and departed by air for Washington, D. C. Command of Joint Task Force One activities in the Pacific now passed to Rear Adm. Fahrion, who had the titles Commander Naval Task Groups, JTF-1, and Commander Advance Echelon, JTF-1. On 26 Aug 46 the administration of JTF-1 activities shifted to Washington, D. C.

On 7 Sept 46, the President announced the indefinite postponement of Test C. On 9 Sept 46 Commander JTF-1 formally terminated preparations for Test C and directed that Operation Crossroads be terminated as soon as practicable.

In accordance with directives from the Joint Chiefs of Staff, Joint Task Force One was formally dissolved on 1 Nov 46. To complete the preparation of reports and summarization of technical data, a Joint Crossroads Committee was established at that time.

31.002 Disposition of Target Vessels.

Twelve out of the thirteen ships sunk as a direct result of the two atomic bomb explosions were not salvaged. The SKIPJACK was brought to the surface on 2 Sept 46.

The HUGHES and the FALLON were beached (on 26 July 46 and 27 July 46, respectively) at Enyu Island to keep them from sinking. DENTUDA was beached at Enyu on 28 July 46. All three were later salvaged. The capsized LCT-1114 was sunk by demolition charges on 30 July 46. ARDC-13 sank on 6 Aug 46 from progressive flooding. LCI-620, damaged by prolonged beaching not directly attributable to either Test A or B, was towed to sea and sunk by gunfire on 10 Aug 46; LST-125 was similarly sunk 14 Aug 46; LCT's 1132 and 1415, although not target vessels, were in condition similar to LCI-620, and were sunk by gunfire near Rongelap 15 Aug 46. Five target vessel LCT's, 414, 812, 1175, 1187, 1237, and LCT-1268 (non-target vessel), in Bikini Lagoon were sunk by demolition charges.

Since dangerous radioactivity persisted aboard the most heavily

contaminated target vessels and impeded salvage, movement, and assessment of damage, the decision was made that these ships be decommissioned at Kwajalein. ComNavTaskGroups was ordered on 16 Aug 46 to shift base to Kwajalein and proceed with the decommissioning of specified ships. This movement to Kwajalein was completed early in September.

The CONYNGHAM, TUNA, DENTUDA, PARCHE, SEARAVEN, and SKATE proceeded from Kwajalein to Pearl Harbor, arriving there on 6 Sept 46; the SKIPJACK was towed to Pearl Harbor, arriving there on 22 Sept 46. These ships were then moved to the San Francisco area for decommissioning and for radiological study.

The remainder of the target vessels were anchored at Kwajalein. Included were: 3 battleships, 2 U. S. cruisers, 1 ex-German heavy cruiser, 1 carrier, 10 destroyers, 12 merchant type ships, 5 LST's, 2 LCI's, 8 LCT's, and 1 YOG.

Plans were made to tow GASCONADE, INDEPENDENCE, FALLON, and CRITTENDEN to San Francisco, to tow HUGHES, PENSACOLA, and SALT LAKE CITY to Bremerton, and NEW YORK and NEVADA to Pearl Harbor -- for detailed structural and radiological examination.

31.003 Disposition of Non-Target Vessels.

The Drone Carrier Unit, Press and Observers Unit, ALBEMARLE, FURSE, BOUNTIFUL, and CUMBERLAND SOUND had sailed from Bikini by 1 Aug 46.

Photographic Carrier Unit, Surface Patrol Group, Drone Boat Unit, BURLESON with all surviving test animals, four PGM's, BAYFIELD, APPLING, two LST's with Army equipment and personnel from Kwajalein and Eniwetok, OTTAWA and ST CROIX with SeeBee equipment, BOTTINEAU and the Army Group had sailed by 10 Aug 46.

Remaining after 10 Aug 46 were: Target Group, Service Group, Seaplane Unit, part of the Transport Unit, HAVEN, and WHARTON.

By 26 Sept 46 all vessels had left Bikini.

The majority of the non-target vessels were transferred from Commander JTF-1 to their prior commands.

31.004 Other Final Activities.

A. Radiological Safety School. On 5 Aug 46 Commander JTF-1 requested the establishing of an emergency radiological safety training program. The scope of the program was later enlarged to train officers themselves capable of forming radiological safety groups within the various services. One important object of the program was to assist in the decontamination and radiological clearance of non-target vessels contaminated in Test B. Another object was to assist in the decontamination research program proposed by BuShips.

Captain G. M. Lyon, (Navy) the JTF-1 Safety Adviser, was requested by Commander JTF-1 to initiate the training program and to act as Director of Training. The Safety Adviser appointed an Officer in Charge of the school, a Training Officer, and an Assistant Training Officer. First plans were drafted on 8 Aug 46; later these plans were outlined in great detail.

On 28 Aug 46 this group arrived in Washington, D. C. and began organization of the school. The first class began 9 Sept 46 at the Navy Department, Washington, D. C.

Students included officers from the Army Air and Ground Forces, Navy, Marine Corps, and U. S. Public Health Service. The training program included a four-week academic course in Washington, D. C., and three months of practical instruction in radiological safety in the field.

B. Joint Crossroads Committee. Following the dissolution of JTF-1 1 Nov 46, the Joint Chiefs of Staff authorized the formation of the Joint Crossroads Committee: "The Joint Crossroads Committee, as an agency of the Joint Chiefs of Staff, will supervise the completion of final supplementary technical reports of Operation Crossroads, the consolidation and dissemination of reports, and the performance of such other duties in connection with the atomic bomb tests as may be directed by the Joint Chiefs of Staff."

The four members comprising the Committee are: Rear Adm. W. S. Parsons (Chairman), Rear Adm. T. A. Solberg, Brig. Gen. T. S. Power, and Col. D. H. Blakelock; Capt. H. R. Carson (Navy) is Executive Secretary.

The Technical Assistants are: Capt. F. L. Ashworth (Navy) and Capt. Horacio Rivero, Jr. (Navy).

The Scientific Consulting Board consists of: Dr. R. A. Sawyer, Dr. N. E. Bradbury, Dr. John von Neumann, Capt. G. M. Lyon (Navy), and Col. S. L. Warren.

The Divisions of the Committee are as follows: Executive Secretary's Division, headed by Capt. H. R. Carson (Navy); Technical Director's Division, headed by Dr. E. S. Gilfillan; Director of Ship Material Division, headed by Rear Adm. T. A. Solberg; Radiological Safety Division, headed by Col. A. A. deLorimier; and Crossroads Documents Division, headed by Dr. W. A. Shurcliff.

C. Radiological Clearance of Target and Non-Target Vessels. On 24 Sept 46 BuShips and BuMandS assumed responsibility for giving final radiological clearance to vessels and prescribed detailed decontamination and clearance procedures for vessels destined to join the active fleet. For ships destined for inactivation or disposal, additional procedures were established.

31.005 Status of Bikini Atoll.

After Test B, and to the extent that radiological conditions permitted, the Survey Unit (Task Group 1.8.5) made further hydrographic surveys, installed navigational aids, and conducted land surveys, all in anticipation of Test C. The Construction Unit continued preparations (begun earlier in the operation) of moorings for the Test-C target vessels; it began construction for instrument towers, blasted out coral heads, and prepared landings at the western islands.

However, following the Presidential announcement that Test C was indefinitely postponed, all survey and construction activities at Bikini Atoll were brought to a close; the Atoll was completely evacuated on 26 Sept 46.

Chief of Naval Operations ordered that surveillance of this area be continued to restrict entry of foreign, merchant, or private shipping which had not been duly authorized.

31.006 Preparation of Reports.

Among the various kinds of reports prepared on the results of the Operation, were these: (a) group reports, by individual groups within the Task Force, (b) Operational Report on the Operation as a military activity, (c) Top Secret Technical Report covering all phases of the Operation but stressing the technical activities and results, (d) Official Pictorial History of Operation Crossroads, and (e) Official Report for the public. These are considered separately below:

A. Group Reports. By Group Reports is meant all individual

reports prepared by individual groups (technical and nontechnical) within JTF-1. Some of these reports were prepared by order of higher authority; others were prepared on the initiative of the group itself. Some were prepared as more or less unique monographs; others comprised regular weekly or monthly series. Some were prepared by the group leaders themselves; others were prepared by specially designated group historians or group reporters.

Some of the more important of the technical reports are listed in the Bibliography attached to this Technical Report.

B. Operational Report. The formal Operational Report of Operation Crossroads as a military activity was prepared by Capt. A. B. Leggett under the direction of the Chief of Staff. This Report, which does not attempt to cover the technical phases of the Operation, was completed in mid-November 1946, and contains over 1000 pages.

C. Technical Report. The Top Secret Technical Report on Operation Crossroads was prepared under the general guidance of R. Adm. W. S. Parsons, Deputy Task Force Commander for Technical Direction.

This Report is the principal over-all summarizing technical report by Commander JTF-1. It is intended for a study by the Joint Chiefs of Staff, by the Evaluation Board, and by other authorized groups.

Preparation of the Report was the immediate responsibility of Dr. W. A. Shurcliff, Technical Historian of JTF-1. He was assisted by Mr. D. Z. Beckler (Deputy Historian), Mr. Peregrine White (Assistant Historian), Mrs. Virginia Shapley, Editor-in-Chief, and by others.

D. Pictorial History. On 10 July 46 the Commander JTF-1 decided that a pictorial history should be prepared partly for general value to the public and partly as a souvenir book for the men who helped in the carrying out of the Operation. This album was to be nontechnical, and was to emphasize the general operational and work-a-day phases of preparing and executing the Operation.

On 31 July 46 responsibility for preparing this pictorial history was given to the JTF-1 Historian; Mr. Peregrine White, Assistant Historian, was named as Editor.

The pictorial history, later named "Official Pictorial History of Operation Crossroads," is being published by the William H. Wise and Co. and has a sale price of approximately $1.65 in Ships Stores and $2.00 at commercial bookstores.

E. Official Report for the Public. The decision was made on 29 Jan 46 by Commander JTF-1 that considerable effort should be made to prepare a textual report for the public on the outcome of the tests. The report was to contain all appreciable technical results which -- in the light of security regulations established by the Joint Chiefs of Staff -- might be released.

Dr. W. A. Shurcliff, JTF-1 Historian, was given the responsibility for preparing this Report.

The manuscript is expected to be practically completed by 1 Jan 47, and the book is expected to be placed on public sale by the Spring of 1947.

F. Motion Picture Films. A number of motion pictures have been made or are being made for showing to technical and nontechnical groups. Some of these films have already been circulated.

Chapter 32

Test-C Prospects

Outline

Section

Chapter 32

Test-C Prospects

32.001 Introduction.

Although Test C, the deep underwater explosion was indefinitely postponed by President Truman on 7 Sept 46, the various pros and cons of eventually holding such a test are still of considerable interest.

The arguments favoring eventually holding a deep-underwater test are these:

A. Although we now have good information as to what happens when an atomic bomb goes off in air or slightly beneath the surface of the water, we have no clear idea as to what the results would be of detonating an atomic bomb at great depth beneath the surface of the ocean. We have no means of estimating the effects with high accuracy. Conceivably the effects might be significantly greater than expected and might provide data of great military and scientific value.

B. According to some sections of the public, the underwater test would "obviously" be the one which would be most damaging to naval vessels; it would "obviously" be the crucial test, re survival of navies; that test is the one the Navy "obviously fears."

C. The underwater test would show how well the atomic bomb would serve to intercept a hostile fleet approaching our country.

D. Only after we have studied a deep-underwater explosion will we be able to interpolate accurately, as in predicting the effects of an explosion at any arbitrary intermediate depth.

E. Some advance preparations have already been made for Test C.

The arguments against holding such a test are these:

A. There is no firm reason for believing that a deep underwater explosion would do more damage than a surface explosion or an explosion at or immediately below the surface; shock effects might not prove to be as overwhelming as some persons expect, and many important atomic-bomb effects would be almost entirely eliminated -- that is, optical radiation, neutron and gamma-ray radiation, would be almost entirely absent.

B. Concentrations of naval vessels are usually to be found in

harbors; but harbors are ordinarily relatively shallow; therefore the deep-underwater test would be irrelevant to principal naval targets (i.e., to the commonest concentrations of naval vessels).

C. Even many important ocean areas are very shallow, e.g., the North Sea and the Atlantic Shelf area.

D. Even though in the past there have been many naval vessel concentrations in open (deep) ocean, it would be an obvious and simple matter for future fleet commanders to space their ships very widely -- as widely as would be required so that not more than one or two vessels would be put out of commission by one atomic bomb.

E. It would presumably be possible for an enemy in advance of outbreak of war to plant atomic bombs in harbors; and it is conceivable that he would be able to pre-train, say, his V-2 type atomic bomb carriers on our harbors; but no such advance preparations or automatic bull's-eyes would be possible for a deep underwater bomb - i.e., a bomb to be used against a fleet moving in open ocean.

F. Even if an enemy could make bombs usable at great depth he might find it difficult to dispatch the bombs quickly to the particular, deep-underwater spot selected. Entirely new techniques and operational procedures would be needed. (If delivery were not made quickly, the target fleet would have time to change course and disperse. If delivery were made by airplane, it is very possible that the airplane would be intercepted and shot down. If delivery were made by submarine, it is quite possible that the submarine would be intercepted and sunk.)

G. An atomic bomb designed for use at great depths would probably be a special-purpose weapon tactically usable only in deep ocean waters. On the other hand an air-burst bomb would be usable the world over -- i.e., over cities, armies, harbors, or fleets at sea, and a heavy-impact atomic bomb for delivery by aircraft for underground or underwater detonation would have broad application, particularly for attacking military or industrial concentrations immediately adjacent to bodies of water.

H. Funds and personnel may continue to be scarce.

32.002 Status of Specifications of Test.

Opinion among principal technical personnel of JTF-1 is to the effect that if a Test C is eventually held, it should conform to these principal specifications:

Depth of bomb:	1000 to 2000 ft.*
Depth of bottom:	At least 2.5 times the depth of bomb.
Number of target vessels:	Few (or none). By obtaining complete data on pressure, the damage which vessels would suffer could be computed with fair accuracy merely from the damage data obtained in Test B.
Number of instruments:	Relatively few; emphasis should be placed on a few well proven instruments very carefully placed, rather than on a great many instruments of uncertain performance placed informally.

(Source: Ref. 300-5; 300-25; 300-26)

33.003 Indefinite Postponement.

On 7 Sept 46, acting with the advice of the Joint Chiefs of Staff, President Truman postponed the Test indefinitely. His statement was as follows:

> "In view of the successful completion of the first two atomic bomb tests of Operation Crossroads and the information derived therefrom, the Joint Chiefs of Staff have concluded that the third explosion, Test C, should not be conducted in the near future...
>
> "The additional information of value expected to result from Test C is such that the Joint Chiefs of Staff do not feel that completion of this test in the near future is justified."

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* By using a depth in the neighborhood of 2000 ft., the troublesome radioactive plume and cloud would be avoided.

APPENDIX I

CALENDAR OF EVENTS

1. Introduction.

A full chronology of "atomic energy" events prior to 1946 is contained in "Report No. 1211 to Accompany Bill 1717, 79th Congress, 2nd Session."

A complete chronology of Queen Day, A-Day, William Day, and B-Day is contained in "Operational Report of JTF-1" by Captain A. B. Leggett (Navy).

The chronology presented below is brief, listing only events of major interest.

All dates and times are local at places concerned unless specified otherwise.

2. Brief Chronology.

Date	Month	Year	
	Jan	1939	The discovery by German scientists of fission of uranium was announced.
6	Dec	41	Decision was made by Dr. Vannevar Bush, Director of the Office of Scientific Research and Development, to undertake an "all-out" effort for the development of atomic bombs for use in World War II.
13	Aug	42	Manhattan Engineer District was established to develop atomic bombs.
2	Dec	42	First self-sustaining nuclear chain reaction was achieved at Chicago.
		1944	Manhattan Engineer District considered using atomic bomb against Japanese fleet at Truk Island.
16	July	45	First atomic bomb was detonated, at Alamogordo, New Mexico. Exact time of detonation was as follows:

Date	Month	Year	(con't)

			Place	Time of Detonation
			Alamogordo, N. M. (MWT)	16 July 0530
			Washington, D. C. (EWT)	16 July 0730
			Greenwich, England (GCT)	16 July 1130

5	Aug (GCT)	45	Second atomic bomb was detonated, at Hiroshima, Japan. Exact time of detonation was as follows:

Place	Time of Detonation
Hiroshima, Japan	6 August 0815
Washington, D. C. (EWT)	5 August 1915
Greenwich, England (GCT)	5 August 2315

9	Aug (GCT)	45	Third atomic bomb was detonated, at Nagasaki, Japan. Exact time of detonation was as follows:

Place	Time of Detonation
Nagasaki, Japan	9 August 1058
Washington, D. C. (EWT)	8 August 2158
Greenwich, England (GCT)	9 August 0158

25	Aug	45	Senator Brien McMahon recommended testing atomic bombs on captured Japanese warships.
28	Sept	45	General H. H. Arnold recommended to the Joint Chiefs of Staff the atomic bombing of captured Japanese naval vessels.
16	Oct	45	Admiral E. J. King recommended inclusion of a few U. S. Naval vessels of modern design in the target array.
10	Dec	45	Plans for the atomic bombing of naval vessels were announced formally.
11	Jan	46	JTF-1 was created and Vice Admiral W. H. P. Blandy was designated Commander.
21	Jan	46	Bikini Atoll was selected as site.
7	Mar	46	Natives were evacuated from Bikini.
22	Mar	46	President Truman directed postponement of the Tests for approximately six weeks.

Date	Month	Year	(con't)
28	Mar	46	Evaluation Board membership was announced.
30	Mar	46	Presidents Evaluation Commission membership was announced.
15	May	46	Commander Joint Task Force ONE hoisted flag on MT. MCKINLEY.
14	June	46	Revised House Joint Resolution 307, authorizing use of certain naval vessels as targets, was signed by the President.
24	June	46	QUEEN Day (Rehearsal for A-Day)
1	July	46	A-Day.
	0555		Bomb carrying plane became airborne.
	0603		Evacuation of Lagoon was completed.
	0850		Bomb-carrying plane started final run.
	0900 (Approx.)		Bomb was released.
	0901 (Approx.)		Bomb was detonated. Exact detonation time (MIKE Hour) was as follows:

Place		Time of Detonation
Bikini	1 July	34 sec (±5 sec) after 0900
Washington, D.C.	30 June(EST)	34 sec (±5 sec) after 1700
Greenwich, England	30 June(GCT)	34 sec (±5 sec) after 2200

	1430		Lagoon declared safe for re-entry of all ships.
	2356		Commander JTF-1 announced the sinking of CARLISLE, GILLIAM, LAMSON, and ANDERSON.
2	July	46	SAKAWA sank.
19	July	46	WILLIAM DAY (Rehearsal for B-Day).
25	July	46	B-Day.

Date	Month	Year	(con't)
	0435		Evacuation of target vessels was completed.
	0620		Evacuation of Lagoon was completed.
	0835		Bomb was aetonated. Exact detonation time (MIKE Hour) was as follows:

Place		Time of Detonation
Bikini	25 July	59.7 sec (±.1 sec) after 0834
Washington, D.C.	24 July (EST)	59.7 sec (±.1 sec) after 1634
Greenwich, England	24 July (GCT)	59.7 sec (±.1 sec) after 2134

Date	Month	Year	
	2311		Commander JTF-1 announced the sinking of LSM-60, SARATOGA, ARKANSAS, YO-160, and LCT-1114. (LCT-1114 was later found capsized and adrift.)
26	July	46	PILOTFISH, SKIPJACK, and APOGON were believed to have sunk, and later these submarines were so listed.
29-30	July	46	NAGATO sank during the night.
10	Aug	46	Commander JTF-1 departed Bikini aboard MT. MCKINLEY.
19	Aug	46	Commander JTF-1 hauled down his flag on MT. MCKINLEY at Pearl Harbor and departed for Washington, D. C.
1	Nov	46	Joint Task Force ONE officially dissolved and Crossroads Board established.

Appendix II

Evaluation Board's List of Information Desired

Section 1. Introduction.

On 8 Aug 46 the Evaluation Board submitted to the Historian's Office a list of information desired. Some of the information desired consists merely of straightforward results of the Tests; other types of information desired consist of information already available in the technical literature and of present interest as bases of comparison or general reference; other types of information desired are more in the nature of predictions, extrapolations, and generalizations which -- at this time, at least -- can be little better than guesses.

This History attempts to include only objectively measured data, simple interpolations, straightforward generalizations, and reference to standard technology already recorded and accepted in the literature.

It is believed that predictions, extrapolations, and generalizations of debatable validity are outside the scope of this History, and should be handled by separate inquiries directed by the Evaluation Board or others, to recognized authorities.

The Evaluation Board's List of Information Desired is presented below, together with comments as to where the information in question may be found.

Section 2. Evaluation Board's List of Information Desired.

Tests in General

1. For each test, one accurate chart showing the outlines of the ships to scale at their best-estimated locations relative to the bomb burst.	See Charts of Chaps. 10 and 20.
2. A table of critical radiological dosages for humans and species of animals used	For persons, the lethal dosages are: Gamma rays: 400 roentgens

in the test, showing variation with the character of the rays.	Slow neutrons: 5 X 10^{11} neutrons per cm^2 Fast neutrons: 1 X 10^{11} neutrons per cm^2
3. A summary of data obtained from observations of animals, including location, shielding effects, and variations from theoretical predictions.	No full analysis available in the office of the Director of Ship Material on 1 Nov 46. See, however, Chap. 15, 19, 25, and 29 for fragmentary comments.

Test A

Re Blast:

4. Composite curves (from all types of data) of blast pressure, impulse, etc., versus distance from the burst.	See Table of Sec. 16.002.
5. Best estimate of ranges at which radar gear and critical radio gear of present design would be put out of action.	See Secs. 13.009, 13.011, and 14.003.
6. Ditto on boiler casings (with steam up).	See Sec. 13.006 and Table 13.1.
7. Ditto on any other damage which would hamper operation of ships.	See Chaps. 13 and 19.
8. Composite curves of repair time required on various types of ships versus distance from the burst.	No curves were available in the office of Director of Ship Material on 1 Nov 46.
9. Best estimate of maximum ranges at which various types of ships would be sunk.	See Chap. 13 for fragmentary answer. No battleships, aircraft carriers, submarines, or U. S. cruisers were sunk.
10. Selected curves of pressure versus time at significant distances.	See Sec. 16.005.

11.	Best estimate of ranges at which unprotected personnel would be killed or incapacitated by blast.	See Chap. 19.

Re Heat and Light:

12.	Best estimate of ranges at which exposed flesh would be burned.	No animals died from flash-burns. Second degree burns occurred on exposed skin at 650 yd, and a few first degree burns as far out as 3000 yd.
13.	Ditto for flesh protected by ointment.	Such protection was excellent beyond 600 yd.
14.	Curves of maximum surface temperature versus distance from burst, for various surfaces.	Values depend on surface thickness, orientation, reflectivity, conductivity, specific heat, and evaporability. No useful data available. See Chap. 14.
15.	Curve of heat-ray intensity versus distance.	No analysis had been made by the office of the Technical Director by 1 Nov 46.
16.	Curve of ultra-violet intensity versus distance.	No data.
17.	Spectrum of the fireball and the intensity distribution therein.	Only limited data available. See Sec. 17.002. Paragraphs B and F, and Sec. 17.003.

Re Initial Flash of Gamma Radiation and Neutrons:

18.	Curves of intensity versus distance from burst.	See Sec. 17.004, 17.005.
19.	Absorption of steel, wood, air, water, brick, concrete, earth, etc. in convenient form to apply to intensity curve.	No data included in this Report.
20.	Range at which direct exposure is lethal to humans.	1350 yd (for gamma radiation) 450 yd (for neutrons)

21. Curves showing thicknesses of steel, wood, water, brick, etc. necessary to shield humans at various distances.	No comprehensive data included in this Report. See, however, Sec. 29.008, Paragraph E re shielding by steel.

Re Residual Radioactivity:

22. Chart of Lagoon showing distribution on ships and in water.	Radioactivity was negligible. See Sec. 17.009 and 17.010.

Test B

Re Underwater Shock:

23. Composite curve (from all data) of peak pressure, impulse, etc., versus distance from the burst. If significantly different, estimated curves for different water depths.	See Sec. 26.002.
24. Best estimate of ranges at which various types of ship or submarine hulls would be ruptured.	See Table 23.1 and Sec. 29.002.
25. Ditto for internal shock damage to put ships out of action.	Same as above.
26. Composite of curves of repair time required on various types of ships versus time at significant distances.	No data were available in the office of the Director of Ship Material on 1 Nov 46.
27. Data on air-blast as for Test A.	See Sec. 26.006.

Re Surface Waves:

28. Height, length, and maximum slope of waves versus distance from the burst.	See Sec. 26.004.

29.	Best estimate of ranges at which various types of ships at various relative headings would be swamped or capsized.	No data. See, however, Sec. 28.004, Paragraph M.
30.	Curves of maximum roll or pitch for various types of ships at various relative headings, versus distance.	Few data available. LCT-1114 at 483 yd capsized; the burst was off her starboard bow. BRISCOE, at 878 yd, rolled 14 degrees. Other non-sunk ships rolled less than 10 degrees.
31.	Best estimates of volumes of water descending from the water column or cloud at various distances from the burst. (In pounds of water per square foot.)	See Sec. 28.001, Paragraph C.

<u>Re Radioactivity and Plutonium Contamination:</u>

32.	(a) Best estimate of quantity of plutonium remaining in water, and (b) the volume of water this will contaminate at maximum lethal dilution.	Re (a): Absolute value is "Manhattan Secret;" relative value is: 10 to 50 percent of all plutonium existing after the detonation. Re (b): Lethality depends on amount taken into body; 50 to 100 micrograms might eventually cause death. Amount in body, not concentration in Lagoon water, is the crucial parameter.
33.	Best estimate of radioactive intensity distribution in the water immediately after the burst, and radioactive decay curve.	See Sec. 27.005 and 27.006.
34.	Curve of maximum volume of contaminated water versus time after explosion.	Neglecting the very slight contamination downwind outside the Lagoon, the volume of water contaminated was: B-Day 0.05 mi^3 1 Day after B-Day 0.8 mi^3 5 Days after B-Day 4.7 mi^3 (Note: Total volume of water in Lagoon is roughly 6 mi^3.)

35.	Critical exposure times (to get lethal radiological dosage) versus distance from burst.	Values range from 30 sec to 3 hr for topside personnel on vessels engulfed by the base surge. See Sec. 29.008, Paragraph E.
36.	Influence of wind, waves, and water current in dispersing contaminated water.	Radioactivity in the water became ganeral throughout the Lagoon within a week. The Lagoon water "half-changes" in 25 days.
37.	Selected radioactive decay curves on various target ships.	See Sec. 27.005.
38.	Selected curves showing intensity of emanations versus distance from contaminated ships.	A small boat roughly 100 yd from a "hot" ship received only negligible gamma radiation from that ship.
39.	Selected curves of beta-ray intensity versus distance from contaminated deck.	The beta radiation had a range of 1 or 2 meters in air.
40.	Selected beta-ray decay curves.	During the first two days, the beta radiation decay rate was greater than the gamma radiation decay rate; in the following days and weeks the decay rates became nearly identical and approached the $1/T^{1.3}$ rate discussed in Sec. 27.005.

APPENDIX III

BASIS OF COMPUTING LOSS OF COMBINED MILITARY EFFICIENCY

1. Introduction.

In the following discussion regarding a definition of combined military efficiency (CME), the following more basic definitions are employed: The military efficiency of a damaged ship is the reciprocal of the number of identically-damaged ships equal in military efficiency to one sound ship. The military efficiency of a ship's (injured) crew is the reciprocal of the number of identically-injured crews equal in military efficiency to one sound crew.

The basis presented below for computing the loss of combined military efficiency, called "Loss of CME", rests on these assumptions:

1. The loss of military efficiency of the ship is known. (This efficiency may be called "$\underline{X}$".)

2. The loss of military efficiency of the crew is known. (This efficiency may be called "$\underline{Y}$".)

3. Each "unit" of military efficiency of the ship depends equally on presence of effective men.

4. It is "half true" that any given man can be transferred to doing any other man's job in an emergency.

5. The fact that there are (prior to Mike Hour) surplus men is just counterbalanced by delays and unbalance in reallocating survivers among the battle stations.

2. Basis.

The computing of the loss of CME is based on these arbitrary rules:

1. If $\underline{X}$ exceeds $\underline{Y}$ (i.e., if crew shortage is most critical), the loss of CME is the average of (1-XY) and (1-Y).

2. If $\underline{Y}$ exceeds $\underline{X}$ (i.e., if the most serious loss of military efficiency is to the ship), the loss of CME is the average of (1-XY) and (1-X).

These two rules reduce to this one:

Loss of CME = $\dfrac{2 - S - LS}{2}$, where $\underline{S}$ is the smaller of the two

quantities, X and Y, and L is the larger.

Examples:

The loss of CME for various assumed values of S and L are as follows:

L (percent)	S (percent)	Loss of CME (percent)
100	100	0
80	80	28
60	60	52
40	40	72
20	20	88
0	0	100
100	80	20
100	60	40
100	40	60
100	20	80
100	0	100
80	60	46
80	40	64
80	20	82
60	40	68
60	20	84
40	20	86

APPENDIX IV

BIBLIOGRAPHY

1. Introduction.

This Section lists reports, books, etc., of interest to persons studying Operation Crossroads. Particular emphasis has been given to technical reports.

References are listed numerically, according to the arbitrarily assigned reference numbers.

Numbers are grouped in these series:

100 Series..........Not used.
200 Series..........JTF-1 General.
300 Series..........Reports by 013, i.e., by the Technical Director and persons responsible to him.
400 Series..........Reports by 014, i.e., by the Director of Ship Material and persons responsible to him.
500 Series..........Other Crossroads reports
600 Series..........Other reports

Within each series the references are arranged more or less according to importance, the more important references being listed first.

2. References of the 200 Series.

Below are listed references by -- or applicable to -- JTF-1 in general.

Ref. No.	Date	Group	Author	Title
201	15 April 46	JTF-1	Chief of Staff	Operation Plan No. 1-46
210		JTF-1	Leggett, Capt. A. B. (Navy)	Operational Report on Operation Crossroads
220	18 Nov 46	JTF-1	Shurcliff, Dr. W. A.	Technical Report on Operation Crossroads

3. References of the 300 Series.

Below are listed references by the Office of the Technical Director (013), or by groups responsible to him:

Ref. No.	Date	Group	Author	Title
300	none	013	Sawyer, Dr. R. A.	Technical Director's Final Report.
300-1	"	"	-	List of Enclosures.
300-2	"	"	-	Introduction.
300-3	"	"	-	Highlights of Coordinator's Reports (later withdrawn, See 300-7).
300-4	"	"	-	Equivalent Energy Tonnage.
300-5	"	"	-	Test C.
300-6	"	"	-	Conclusion.
300-7	"	"	Sawyer, Dr. R. A.	Survey of Results.
300-8	"	"	Gilfillan, Dr. E. S., Jr.	Untitled paper on probable effects of A-Day nuclear radiations on crews.
300-11	"	"	Debenham, J. K. and Archer, H. M.	Report of Determination of Burst Height, Test A. Encl. A.
300-12	18 Oct 46	"	Archer, H. M.	Determination of Ship and Burst Locations for Test A and B.
300-13	27 Sept 46	"	Penney, Dr. W. G.	Air Blast and Water Shock in Tests A and B.

Ref. No.	Date	Group	Author	Title
300-14	31 July 46	013	Gerlach, Comdr. C. H.	Report on Ships Instrumentation Other than Air Blast and Underneath Pressure; Encl. C, Part 2.
300-15	7 Sept 46	"	Penney, Dr. W. G.	Reasons for Expecting Peak Pressure to Fall Off with the Radius Faster than R^{-1}; Encl. D.
300-16	7 Aug 46	"	Revelle, Comdr. Roger	Coordinator's Report on Oceanographic Work at Bikini and Surrounding Areas; Encl. E.
300-17		"	Thatcher, Dr. E. W.	Summary Report on Electromagnetic Propagation; Encl. F.
300-18	30 Sept 46	"	Hulburt, Dr. E. O.	Summary of Radiometry Measurements of Atomic Bomb Tests at Bikini in July 46; Encl. G.
300-19	27 Sept 46	"	Vaux, Comdr. George	Preliminary Evaluations of Remote Measurements of Tests A and B.
300-20	25 Sept 46	"	Warren, Col. S. L.	Nuclear Radiation Effects in Tests A and B, Preliminary Report of.
300-22	1 Sept 46	"	Hirschfelder, J. O. and Magee, J. L.	A critical Summary of Some A-Shot Measurements.
300-23	30 Sept 46	"	Holloway, Dr. M. G.	Summary of Project Y Crossroads Activities

Ref. No.	Date	Group	Author	Title
300-24		013	Gilfillan, Dr. E. S., Jr.	Time Interval Between Arrival of Primary and Reflected Shock Wave (Milliseconds). (one page chart.)
300-25		"	Penney, Dr. W. G.	Depth for Test C.
300-26	15 Oct 46	"	Von Neumann, Dr. John	Comments concerning Dr. W. G. Penney's Memorandum, "Depth for Test C."
300-27	(Same as 300-16)			
301		"	Wyckoff, C. W. and Shafton, Comdr. K.	Combined Projects, Test B, II-11, IX-16, Parts I and II.
302	30 Oct 46	013B	Revelle, Comdr. Roger	Some Rough Calculations Concerning the Amount of Water in the Column. JTF-1/013B/ms; Serial 65 (013B).
303	23 July 46	013E	Warren, Col. S. L.	Results of Radioactivity Measurements of Test, Preliminary Report.
310	13 Nov 46	013E	Scoville, Dr. H. P.	Memorandum entitled "Time of Onset of the Effects from Radiation Exposure."

4. References of the 400 Series.

Below are listed references by the Director of Ship Material, or by groups responsible to him.

Ref No.	Date	Group	Author	Title
410	4 Aug 46	014	Solberg, Rear Adm. T. A.	DSM Interim Report for Test A, DSM Serial 00441.
410-1	30 July 46	014B-H	Frederick, Col. G. D.	Army Ground Group T. G. 1.4, Interim Report for Test A. Encl. B to DSM Serial 00441.
410-2	28 July 46	014J	Lonnquest, Capt. T. C. (Navy)	DSM Bureau of Aeronautics Group. Interim Report for Test A. Encl. C. DSM Serial 00441.
410-3	29 July 46	014K	Forest, Capt. F. X. (Navy)	DSM Bureau of Ships Group. Interim Report for Test A. Encl. A. DSM Serial 00441.
410-4	30 July 46	014L	Mott, Capt. E. B. (Navy)	DSM Bureau of Ordnance Group. Interim Report for Test A. Encl. D. DSM Serial 00441.
410-5	28 July 46	014M	Draeger, Capt. R. H. (Navy)	DSM Bureau of Medicine and Surgery Research Group. Encl. E. DSM Serial 00441.
410-6	28 July 46	014N	Engleman, Capt. C. L. (Navy)	DSM Electronics Coordinating Officer. Interim Report for Test A. Encl. F. DSM Serial 00441.
410-7	26 July 46	014S	Fraser, Comdr. O. W.	DSM Bureau of Supplies and Accounts Group. Interim Report for Test A. Encl. H. DSM Serial 00441.

Ref. No.	Date	Group	Author	Title
410-8	26 July 46	014Y	Lamoreaux, Comdr. R.	DSM Bureau of Yards and Docks Group. Interim Report. Encl. G. DSM Serial 00441.
420	27 Aug 46	014	Solberg, Rear Adm. T. A.	DSM Report on Decontamination of Target Vessels. Interim Report for Test B. Encl. F. DSM Serial 00447.
420-1	27 Aug 46	014	Solberg, Rear Adm. T. A.	DSM Interim Report Test B. DSM Serial 00447.
420-3	20 Aug 46	014J	Dodson, Capt. J. E. (Navy)	DSM Bureau of Aeronautics Group. Interim Report for Test B. Encl. B. DSM Serial 00447.
420-4	27 Aug 46	014K	Forest, Capt. F. X. (Navy)	DSM Bureau of Ships Group. Interim Report Test B. Encl. A. DSM Serial 00447.
420-5	26 Aug 46	014L	Mott, Capt. E. B. (Navy)	DSM Bureau of Ordnance Group. Encl. C. Interim Report Test B. DSM Serial 00447.
420-6	6 Sept 46	014M	Draeger, Capt. R. H. (Navy)	DSM Bureau of Medicine and Surgery Research Group. Interim Report Test B. Encl. E. DSM Serial 00447.
420-7	22 Aug 46	014N	Rice, Comdr. J. E.	DSM Electronics Coordinating Officer. Interim Report Test B. Encl. E. DSM Serial 00447.

Ref. No.	Date	Group	Author	Title
420-8	15 Aug 46	014Y	Diberto, Lt. E. T. (Navy)	DSM Bureau of Yards and Docks Group. Interim Report for Test B. Encl. D. DSM Serial 00447.
421	27 Aug 46	014B-H	Frederick, Col. J. D.	Army Ground Group. Final Report of Atomic Bomb Tests. T. G. 1.4.
430	6 July 46	014	Solberg, Rear Adm. T. A.	Gross Damage Report Test A. DSM Serial 00174.
440	5 Aug 46	014	Solberg, Rear Adm. T. A.	Gross Damage Report Test B. DSM Serial 00443.
450	19 Dec 46	014	Solberg, Rear Adm. T. A.	Final Report on Tests A and B by BuShips Group.

5. References of the 500 Series.

Below are listed references by other persons and groups within Operation Crossroads.

Ref. No.	Date	Group	Author	Title
500				Crossroads Handbook, LA 550.
510-1	9 Sept 46	1.5.2	Cullen, Col. P. T.	Descriptions of Bursts.
510-2	10 Sept 46	1.5.2	Cullen, Col. P. T.	Aircraft Orbit Positions.
510-3	30 Sept 46	1.5.2	Cullen, Col. P. T.	Photo Installations in Aircraft.

6. References of the 600 Series.

Below are listed references by groups and individuals not in Operation Crossroads.

Ref. No.	Date	Group	Title
601	11 July 46	Evaluation Board	Preliminary Report on Test A.
602	27 July 46	Evaluation Board	Preliminary Report on Test B.
603	7 July 46	President's Evaluation Commission	Preliminary Report on Test A.
604	27 July 46	President's Evaluation Commission	Preliminary Report on Test B.

APPENDIX V

PHOTOGRAPHS

TEST BAKER

THIS SEQUENCE SHOWS THE B-DAY EXPLOSION. NOS. 1, 2, AND 3 ARE SUCESSIVE FRAMES; NO. 4 IS NOT CONSECUTIVE. NOTE THE MINIMUM OF OPTICAL RADIATION IN NO. 2.

REF: 16 MM ROLL #1428 E.

NO. 1

NO. 2

NO. 3

NO. 4.

APPENDIX V

THE FOLLOWING PHOTOGRAPHS FROM TEST B ILLUSTRATE:

1 Test-B fireball breaking through surface of the Lagoon.

2 Same an instant later, showing embryo shock wave forming on each side of the column. Note sudden bend in shock wave close to the column.

3 Same an instant later. Shock wave now appears nearly spherical.

4 Aerial view of Test B prior to formation of condensation cloud. Shock wave has engulfed SARATOGA (left) and ARKANSAS (right).

5 Start of formation of condensation cloud.

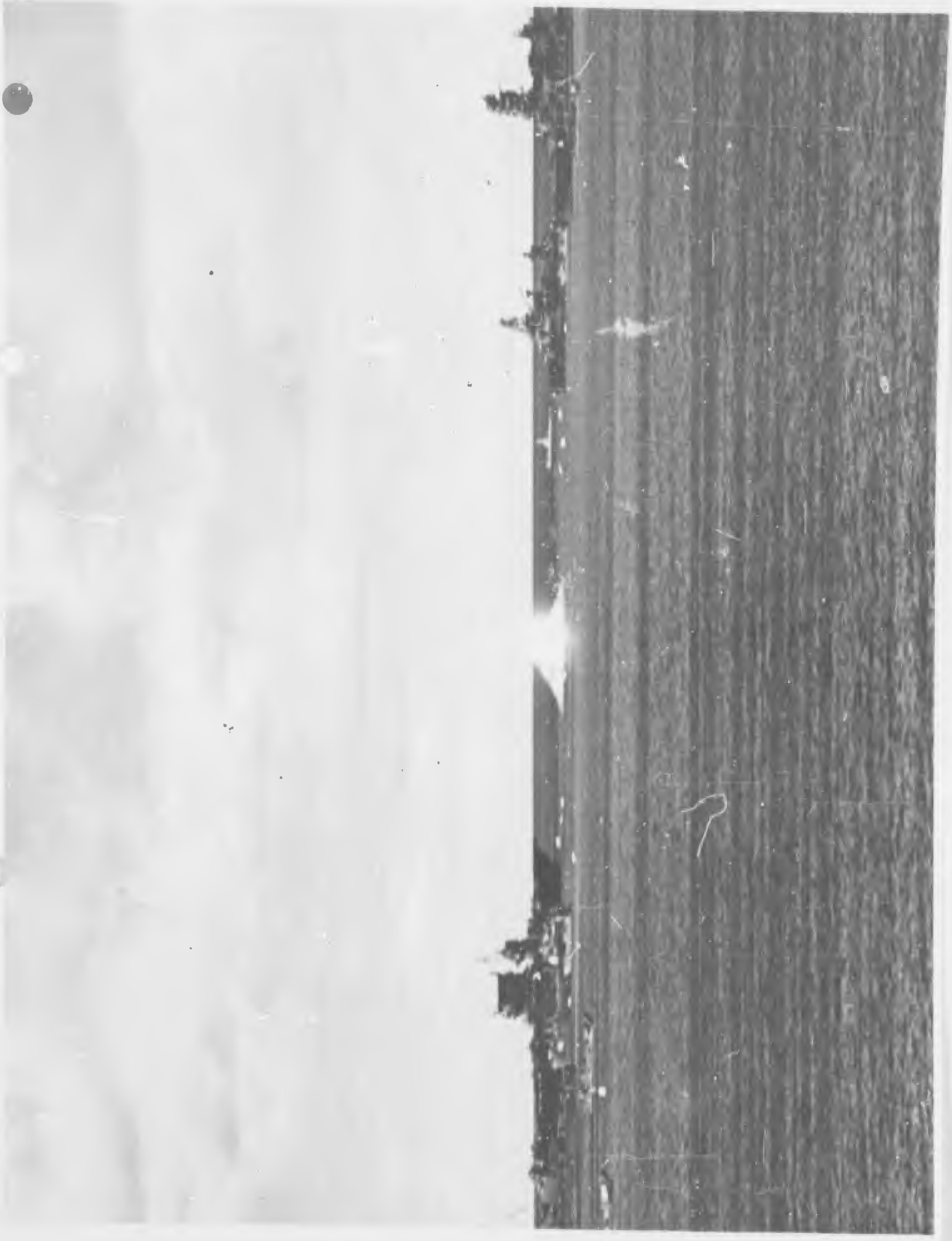
6 Aerial view of condensation cloud in early stage. Streaks to left of center, top of column, presumably show paths of fragments from LSM-60.

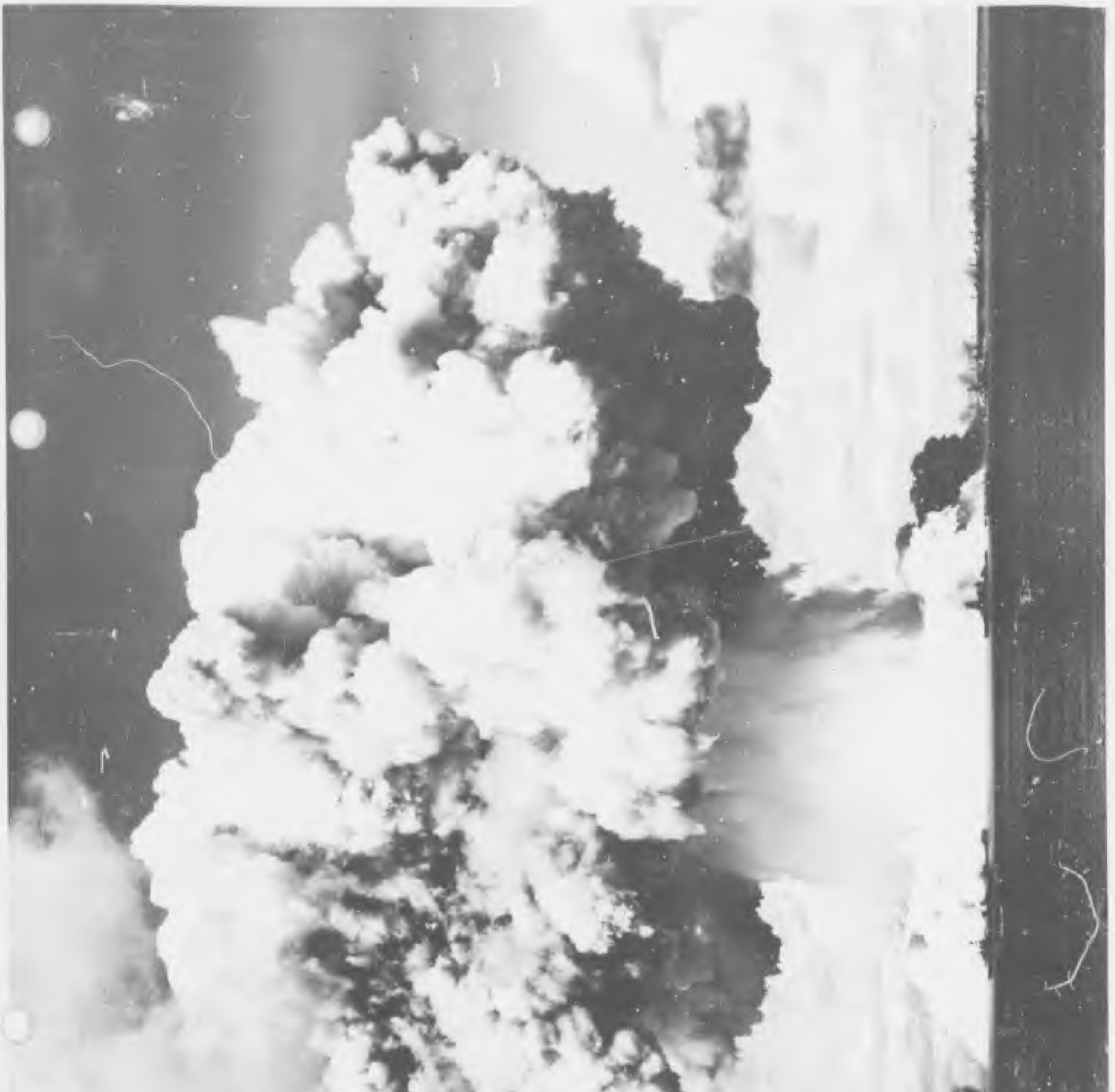
7 Base surge produced by descending column.

8 PENSACOLA: ruptured 16 in. X 3/8 in. stanchion extending from boiler foundation to second deck. (Stanchion was perhaps weakened in Test A)

9 PENSACOLA: Gun turret #2 lifted off the base ring.

10 PENSACOLA: Forward engine room; cracks in #4 astern turbine foundation casting.





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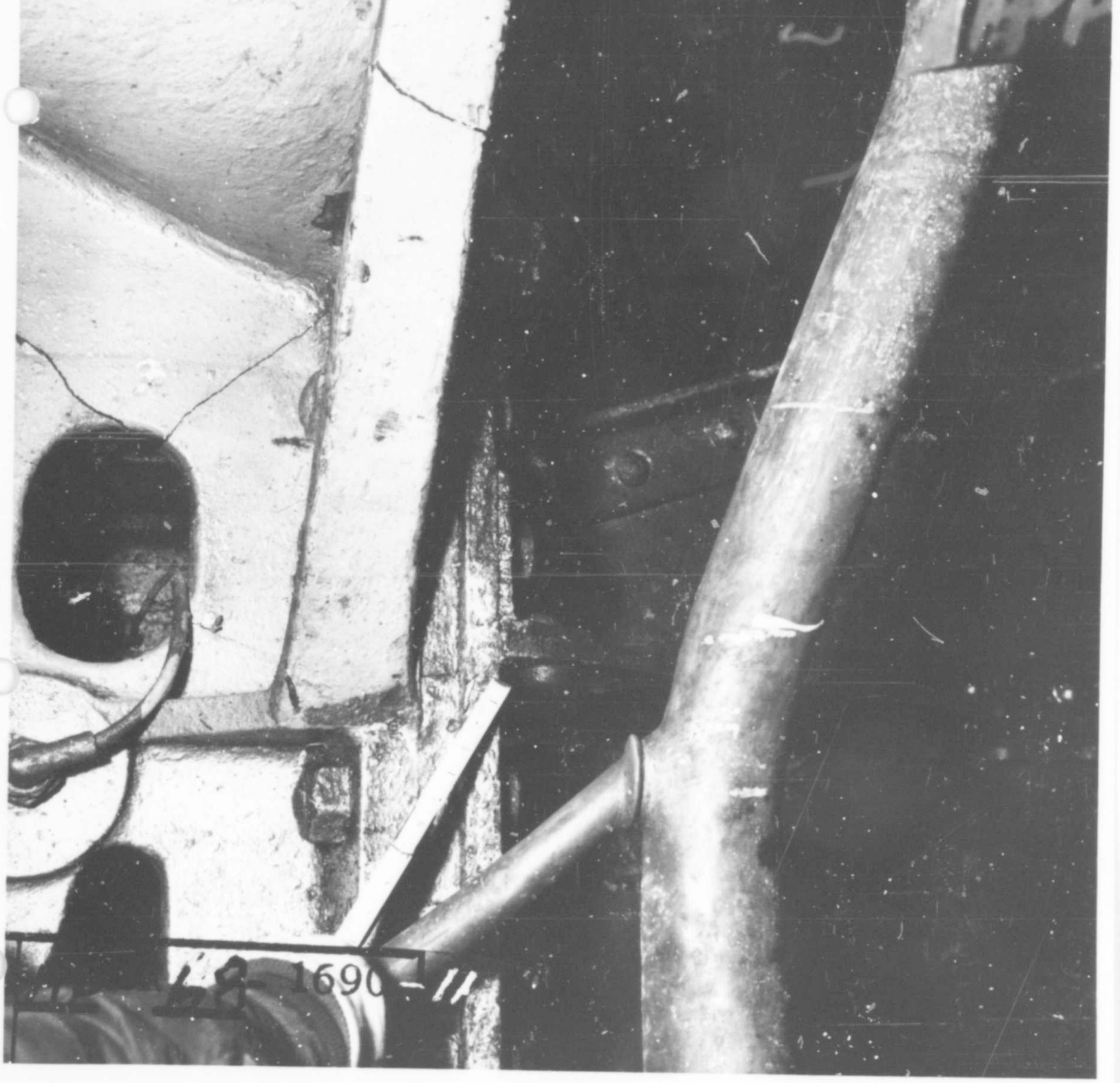
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